STANDARD PRACTICAL PLUMBING.

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BEMROSE & SONS
LIMITED
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DERBY
AND
LONDON

Dedicated

TO THE

PLUMBING CRAFT.

This work having been accepted and appreciated by everyone who has seen it, and its merits acknowledged by thousands of letters, including one from His Royal Highness Albert Edward, Prince of Wales, K.G., authorised by letter from Sandringham, Norfolk, dated the 19th day of January, 1896, wherein it says that "His Royal Highness will be happy to accept the copy which you have been so good as to send him," I humbly acknowledge my grateful sense of such general appreciation, and as a practical working Plumber most respectfully dedicate this work to Practical Plumbers, and hope that the Second Volume will assist in facilitating the teaching of practical and technical Plumbing, and in every way promote the spread of our ancient trade in this our nineteenth century.

Your very obedient Servant,

PHILIP JOHN DAVIES,

Member of the No. 1 *Lodge of the United Co-operative Plumbers' Association of Great Britain and Ireland, and Registered Teacher of Plumbing, Gresham College, London,* 1882.

78, EARL'S COURT ROAD,
KENSINGTON, LONDON.

of January, 1896.

PREFACE.

DOUBTLESS my fellow-workmen thought that a second volume of this work was never coming. In fact, I have been told, over and over again, by those who have had some little dealings with the work, that I should not be able to complete it.

However, I am pleased to say that I am not one of those to throw up the sponge at anything that is not an impossibility.

The work is all the better for being kept back, because I have had another ten years (thus making in all thirty-five years on the work) to put in matter, which would have been impossible had I printed the second volume when it was announced, viz., about the year 1886, since which time there have been some big strides made with water companies and bacteriological knowledge. Besides this I have been able to devote the greater part of this time to ancient water supply, which I trust will be both useful and interesting. I have also been able to get statistics from foreign countries, of which I knew nothing when I published the first volume.

I have also been able to complete my experiments in chemistry, the whole of which I have lately *re-worked* out, in conjunction with well-known chemists, in order to make it more certain and trustworthy. There is also the hydraulic ram work, which could not have been in this volume ten years ago, nor could I have put in those useful and interesting illustrations of the injectors and ejectors, to say nothing about the pumps and turbines, so that you will be amply repaid for the waiting. You will find that I have treated the pump work most exhaustively. Many of the things therein contained are most ancient, though quite new to the present age, to say nothing of the many new lavatories and baths which have been added.

My object has been to make this work what its name implies, viz.—a standard trade work, giving the history of what has been done; for it is a common occurrence to find old methods brought out under new titles, and palmed upon the workman as something quite new, but which more often than not turn out to be old disused articles. This is not all, I have endeavoured to guard my younger readers against doing work twice over, and to look out for the future, especially my country brethren having to do with drainage and water supply, and to steer clear of all chances of water contamination, or losing the sources of water supply.

I have also given him a fair drilling against assuming the title of sanitary engineer, but to stick to his old trade name, and raise himself above the condition in which the trade was, when I began to write this work in the year 1862.

And it will be remembered that about a month before I commenced this work, we lost one of the brightest men that ever England possessed. I refer to the late Prince Consort. Now I hesitatingly say that in the middle part of this century, through the neglect of those whose duty it ok after hygienic principles, such as *Doctors*, *Sanitary Engineers*, *Architects*, and *Builders*, all, by not looking after their work as became them, as a body, became dilatory, and ondon and the country was grossly neglected.

The plumbers were equally to blame; this was not all, but they became masters of the situation, proud-stricken, thinking themselves above everyone with whom they came in contact. They by so doing, created an ill-feeling amongst those that employed them, and sooner than have some of these plumbers in the house they would rather employ an ironmonger. These ironmongers saw that they could substitute inferior metals for lead, whereby the blacksmith's handicraft could be employed. Now the ironmonger, to make himself appear an important individual, arrogated to himself the title of SANITARY ENGINEER, and from that day to this the title is largely used by rank outsiders. And the builders were equally at variance with the plumbers, and they sought a cheaper way to carry out the work, and would only employ those belonging to the Trade Societies if they could help it, because here, if a man misconducted himself, or did his work slovenly, the individual would be brought to book, but when the blacklegs found that they had to behave, they would not join the Trade Society, but worked a day here and a day there, or got into some builders' firm (under price) who knew little or nothing about the real plumbing work, and thus they went from builder to builder until the builder again had been bitten.

Now this was intolerable; the builder was compelled to get his work done at a price, which was the cause of zinc roofs and gutters, iron soil pipes in lieu of lead, iron service or communication pipes, and when once they could see that they could oust the plumber they lost no opportunity to do so, making all sorts of excuses, such as lead water pipes are poisonous, rats eat leaden soil pipes, and such like nonsense, and by the introduction of this, they have been the main cause of the loss of tens of thousands of lives from typhoid and other fevers.

Now we, of the present day, are saddled with all this, but happily now, we who have respect for our work, are regaining the individuality of our forefathers, who established for themselves *legitimate* and practical Trade Societies which at that time none but practical plumbers were allowed to enter, which we are now rapidly resuscitating, and there is every prospect of the status of the trade being as it was of old, and let it be so.

In the first volume I thought it proper to apologise to my readers for the apparently extreme length of this work, and if it were necessary to do so then, it is doubly so now, but I may really excuse myself from this second apology because of the many difficulties that I have had to surmount during the last ten years. You will find that the historical part of the water supply has been almost lost, and I have had to get it through old and almost forgotten documents in the King's library at the British Museum (the admission ticket of which I have held since April 2nd, 1879, No. 1145, A 11), and also such places as the Record Office, hunting books, the greater part of which are in Latin and Greek, so that the expense incurred has been fabulous to a plumber who has all his lifetime had to work for his living.

INTRODUCTION.

IN the Introduction to Vol. I. I said that plumbing, " as practised in England, demands a very extensive range of knowledge." Truer words were never written, for there are to-day many so-called excellent workmen, advanced in life, who have never reached the platform of technicality in connection with their calling. They have mastered many simple roof jobs, or making joints, and fixing a few of the sanitary contrivances to be found in the market; but many of these proud-stricken individuals are at a sad loss should they have some out-of-the-way apparatus to fix, such as a sulphate plant; more especially should they get a bit of good cast sheet lead to work. In point of fact, I have seen them terribly put about by turning or flanging down the inlet of a cast lead trap, and personally have had many a time to show them how to go about the job without splitting the lead. This is a common occurrence with the flash joint-wiper and quasi-plumber. Others have an idea that it is a sort of hereditary affair, always boasting about what their fathers or uncles did; some even go back to swagger about what their grandfathers did, and think that they are the only men that cannot be approached. I need not say that such men are, as a rule, little else than mere automatons. These are the men that have let the whitesmiths, braziers, bellhangers, gasfitters, and general ironmongers into the trade, for you must understand that these latter men are not, usually, dunces, and can see the flash jointer's and quasi-plumber's folly.

Plumbing does not merely consist of house plumbing, viz., making joints, bending a bit of soil pipe, or putting in a gutter, which are about the first things a lad should learn. This, in reality, is only the preparatory education of a plumber; in fact, I much question whether we have any limit to what is required for a plumber to know, for, no matter what business it is, the chances are that you will find that the plumber has had some finger in the pie. Take, for instance, the building trade. What is more important than this, though small, portion of the plumber's work? In the country and in London he is the first on the scene with his pumps, or the building supply. He next is engaged running up suitable pipes, which, if done in the carcasing, is done cheaper and in many cases much better, and, finally, he is engaged on the roofs and fixing sanitary fittings, &c. Then we will look at the plumber's work on board ship. Here his work has to be of the very best class. Then in the Gas Works; the plumber is a most important individual, and such work must be of the A 1, copper bottom, : for he is often called upon to make saturators with sheet lead from ¾in. to 1in. thick, and fix most intricate forms of the like substance. Next we will take the Oil Mills and Oil lso the work has to be of the very best class, especially the tanks for refining

cotton oil. Then we will take you into the Copper Works. Here the plumber has gigantic leaden apparatus to make and look after for making sulphate of copper, which work requires a thorough knowledge of pumps, injectors, acids, and of the properties and qualities of lead. Then the plumber is one of the most useful men in Brew Houses, Distilleries, Sugar Refineries, and lastly, the Chemical Works, and in scarcely one of these places is the work of a plumber alike.

I could name scores of other places where the plumber is required, and, *de facto*, looked up to as one of the most important mechanics in these manufactories or works.

Now, what do we find in London? Some very good men at what is known as the London plumbing, viz., fixing closets and running the piping necessary for a dwelling. It is very rarely that such plumbers are good roof men. But, even let them be good roof men, with such scanty knowledge they must, when they come to think of these things, admit that they have only a portion of the knowledge of a plumber, and remember this, that the London plumber has no chance whatever of doing well or ram work, and this is one reason why I have so exhaustively treated the subject of ram and pump work. But don't for one moment suppose that by reading, and even learning, this book by heart that it will enable you to do the work without the practical part; but it will teach you how to go about your work more readily, and if you combine my writings with your practical work, then you will have a far better chance of getting on than you could otherwise.

Of course I am not pitching into the house plumber alone, for many of the plumbers found about Chemical Works are equally as much to blame. They seem to be born, and many of them buried, at one place, without knowing how to properly make a joint; and as to touching a bit of house plumbing proper, why I would sooner give the work to a carpenter!

Then there is another thing—some of the house plumbers have an idea that they ought not to do lead burning. Then some of the Chemical Works' plumbers cannot do house plumbing. On the other hand, some of the plumbers of the Chemical Works think that the house plumber should not do work in a Chemical Works. But this is a sad mistake, for no plumber that is worthy of the name of a plumber in 1896 should rest at this, or encourage such thoughts, for a plumber should know every branch of his trade, because it is not a difficult trade—in fact it is a simple trade—covering a large range of work; and without a thorough knowledge of such he cannot go about it systematically to make it pay, nor can he tell where to look for and guard against defects. Remember this any ordinary person can teach himself to make a joint, to burn lead, apparently well; but look at the difference in the time the properly-taught or well-versed workman takes compared with that of the unsystematically-taught workman. The first keeps the trade together and the other drives it away, and accounts for the status of the plumbing trade, which is ever changing.

This work is original, and a book that has come from nothing but practice. It was the pioneer, begun in 1862, and a large portion has gone through different trade journals, especially the *Builder*, *Building News*, *English Mechanic*, *Plumber and Decorator*, and at least a dozen other journals besides, and since the first publication of this work, if you look around you will find many books which are nothing more nor less than copies.

In conclusion, I must thank my thousands of readers for the extraordinary amount of praise which they have lavished upon these writings, and especially over the first volume. I have answered many of them personally, and have appended a *facsimile* of two, out of at least 5,000 or 6,000, which I am proud of. The writer of the first of these, so far as I can remember, I have never seen or heard of before.

I shall always be glad to continue answering questions, and giving my readers any hints or instructions within my power, by their communicating direct to 78, Earl's Court Road, Kensington, London.

MEMORANDUM.

FROM
A. W. LENEY.
Builder, House Decorator,
GAS, HOT-WATER & SANITARY ENGINEER.
39 Goldstone Villas
HOVE.
ESTIMATES & PLANS PROVIDED FOR EVERY DESCRIPTION OF WORK

REPAIRS OF EVERY DESCRIPTION
TO HOUSE PROPERTY.
SPECIAL ATTENTION
GIVEN TO SANITARY WORK

REGISTERED BY THE WORSHIPFULL COMPANY OF PLUMBERS
MEDAL AND 1ST HONOURS AWARDED BY THE CITY GUILDS OF LONDON INSTITUTE

October 19th 1895

To J. P. Davies Esqre
78 Earls Court Rd
London.

Dear Sir

Have heard with great amount of pleasure that you are publishing Vol II "Standard Practical Plumbing." will you kindly let me know at your earliest when it will be ready & price of same. At same time will you kindly accept my very sincere & hearty thanks for the many pleasant & profitable hours that Vol I has given me. In dropping you a line, it seems as if it were to an old friend one meets daily, to whom the the general "How do" & the hand shake conveys the mutual good feeling so well understood by the two interested. I am instructor to the Plumbing Class here we have about thirty students, you would be pleased to hear the s[illegible] "Will you lend me Davies' Plumbing this week Sir." I might say that if [illegible] any other works that you could recommend, I should be very grateful [illegible] compliments [illegible] Be[illegible] Yours faithfully A W Leney. R.P.

The following is the second letter referred to:—

W. P. BUCHAN.
SANITARY & VENTILATING ENGINEER

36-38 Renfrew Street
Glasgow 29 Nov 1895

"Standard Practical Plumbing"

P. J. Davies Esq
78 Earls Court Road. Kensington
London. W.

Dear Sir

The many who read Vol. 1. of your "Standard Practical Plumbing" brought out in 1885 will be glad to learn that there is good prospects now of Vol. 2 being soon in the market. The proof sheets of Vol 2. which I have just seen show that the new volume is to be quite as elaborately illustrated as the last one so that the book will be valuable not only to the rising generation of apprentices but also to journeymen plumbers and to all who are interested in plumbing work.

Wishing you all good success in your new Volume I am

Yours truly
W. P. Buchan
R.P.R.
Author of W.P. Buchan's Plumbing

CONTENTS.

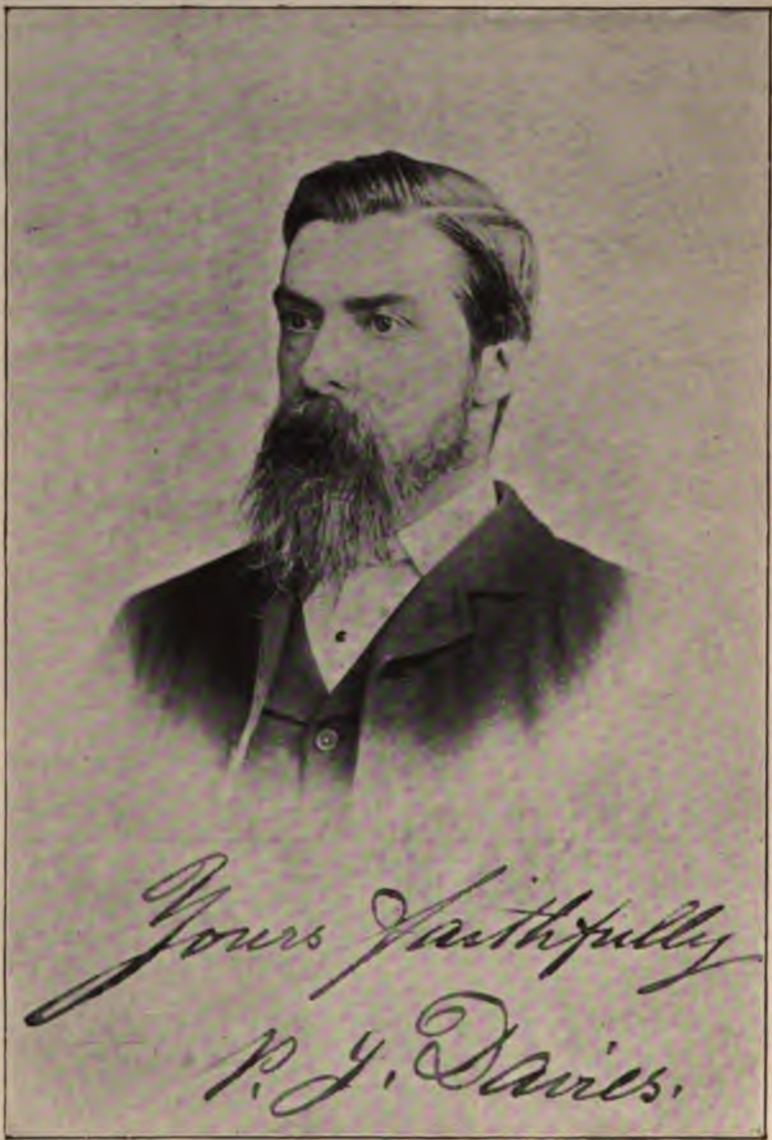
NOTICE.

Owing to the multitude of letters of enquiry, &c., sent to the Publishers of this work and to the Author, it is earnestly and respectfully requested that, to avoid delay, all technical and other communications be forwarded to me, the Author.

I shall then be able to answer any questions in reference to the subjects contained in the two Volumes, or relating to the Plumbing Trade in general.

A stamped addressed envelope must accompany all letters of enquiry.

PHILIP JOHN DAVIES,
78, Earl's Court Road, Kensington,
London, England.


Yours Faithfully
P. T. Davies.

STANDARD PRACTICAL PLUMBING.

WATER SUPPLY.

Wells.

IN the remotest of ages of antiquity, the men in the East considered the construction of wells, fountains, and cisterns to be one of the greatest acts of benevolence they could perform towards their fellow-creatures. In fact, rich men considered it a moral duty to devote a certain portion of their wealth to the digging of wells and the building of cisterns for the supply of the thirsty traveller.

We will now proceed to the description and illustration of some of the most ancient wells, many of which date nearly three thousand years before the Christian era. We will commence with the oldest of which we have any record, namely, those dug by Abraham, at Beersheba, over 4,460 years ago. Of course, thousands of years passed before man was equipped with the necessary tools for digging such wells as at Beersheba. The next in point of antiquity, although of much more importance, is Jacob's well, a description of which should interest all connected with this subject, more especially on account of its great antiquity, it having been made at least 3,600 years ago, and of its wonderfully perfect state of preservation. This well is situated at Sychar, on the road to Jerusalem, and is 105ft. deep, and 9ft. in diameter, sunk into the solid rock. Its standing depth of water is about 15ft. Next we come to Joseph's well at Cairo. It is of an oblong shape, and sunk through the solid rock, and measures 18ft. by 24ft. The depth of the first well is 165ft., which is shown at B, Fig. 770, page 366. At this point there is a large chamber cut in a lateral direction as at E. This is for the horses, mules, or asses to work the lower well-buckets. The second well is 130ft. by 9ft. The total depth of the well from its surface to the gravel bottom is 297ft., 2ft. being allowed for the dipping buckets at R.

There are various opinions respecting this well and its date: some attribute it to Saladin, whilst others believe it to be the work of a more scientific people, probably the production of those that built the wonderful Pyramid and the unrivalled monument of Thebes, Dendarah, and Ebsamboul. You should also know that Cairo is supposed to occupy the site of Egyptian Babylon, and this well to be the remains of that ancient city. There is also a good reason for its oblong shape, viz., to better enlighten its interior by sooner receiving and retaining longer the rays of the sun. Nearly every writer on history has had something to say about wells.

In times of war wells were covered up and the enemy thereby defeated. Even David took this course against the Ammonites. The Bible is full of mention on wells and rivers, and a Persian story is told of Armenian patriarchs ...re concealed several years in a well during the ... of the Christians under Diocletian and

Wells stand as landmarks for the most celebrated cities of the ancient world. Heliopolis, Syene, and Babylon in Egypt; of Tyre, Sidon, Palmyra, Nineveh, Carthage, Utica, and Barca are all gone, but their wells still are in existence; Jerusalem's Temple has gone to the winds, but Siloah's fountain still flows, and the Kedron is still flowing through the valley of Jehoshaphat. There is also to be seen the pool of Bethesda, 150ft. by 40ft., with its large curb stones well cramped with iron, and lined with cement and flint.

Well Heads.

Curbs or parapets were generally placed round the mouths of wells, and of a very costly nature, often of massive marble, ornamented with highly wrought sculptures from 20in. to 36in. in height. I have just seen two such curbs or well heads made from Corinthian caps at the Olympia, West Kensington, and should advise my reader to inspect same if he gets half a chance; and though these heads are of recent date, they give the correct idea of those of the ancients.

Many of my junior readers may ask why it is that some wells are so much deeper than others, whilst others may ask for a short account of the theory of springs. The latter question, when answered, will fully explain the former.

Rain, Origin of, Springs.

It may interest you to know something respecting the cause of rain (see Sun's Rays, change of climate in South-Western Asia, and Steam in Hot Water introduction, also see pages 135 and 136, Vol. I., where I have drawn your attention to the annual amount of rainfall in England). I now will briefly explain what produces this rain.

In the first place it is formed by the mixture of two gases, namely, oxygen and hydrogen, the former being sixteen times heavier than the latter, these gases combining in the proportions by volume, of one volume of oxygen to two of hydrogen, produce water, and the production of water by the combination of hydrogen in the air may be easily demonstrated by the difference in temperatures of the inside and the outside of a window, or by bringing an inverted cold, dry, bright glass or jar containing air over the flame of the hydrogen blow pipe, see Fig. 74, Vol. I. (*without the aid of air or wind*), when the glass or jar at once becomes dimmed, owing to the condensation of water in small drops upon the dry, cold surface of the glass. Now, through these two gases encircling the whole earth, we are partially indebted to it for our water supply, together with the constant changes of heat and cold.

Air at a given temperature can only contain a certain quantity of moisture in solution, and when this maximum quantity is arrived at it is said to be saturated with aqueous vapour, and the warmer the air the greater will be the

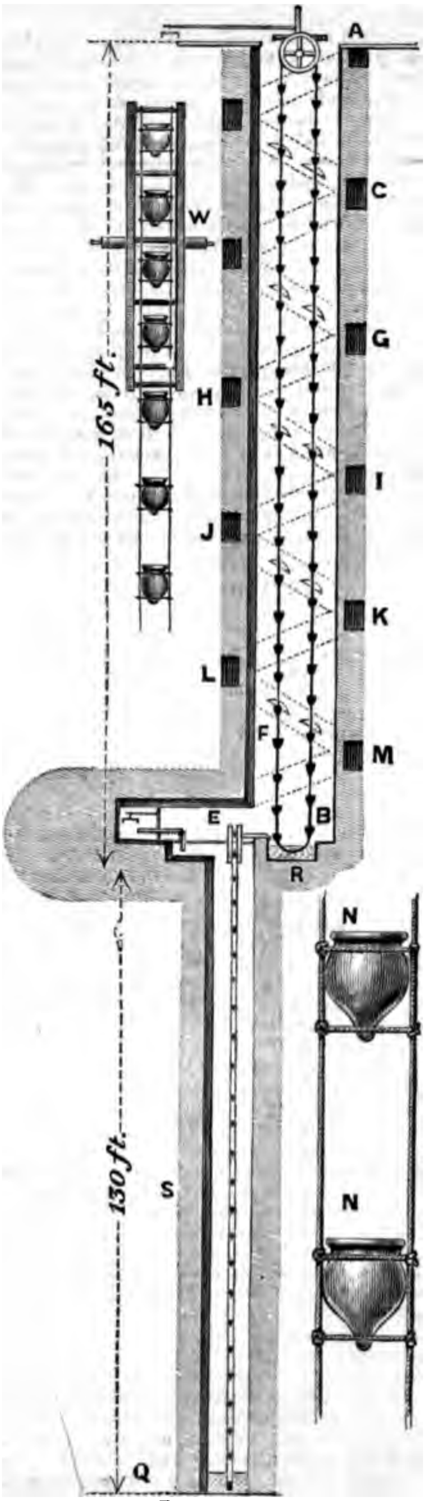


FIG. 770.

amount of vapour contained, and when this saturated air is suddenly cooled (as in the experiment with the hot air and cold glass), water is deposited in very fine globules forming a mist, cloud, or fog, and which is known as a rain cloud, which rain cloud if overcharged with this condensing vapour the aqueous vesicles of the gathered mist at first grow large and heavy, and several of them will coalesce and form themselves into a liquid drop, which, when it has reached $\frac{1}{75}$th of an inch in diameter, descends by the influence of its weight through the air, and should the rain drops commence falling from a, comparatively speaking, high or chilled region of the atmosphere, it grows larger as it reaches the warmer and moister regions below, and here condenses more moisture upon itself until it has attained large drops fully a quarter of an inch in diameter, which will at times acquire a velocity of 34ft. per second in falling, but never more, on account of the resistance of the air, which prevents any further increase of speed beyond that amount. A drop of rain $\frac{1}{25}$th of an inch in diameter cannot possibly acquire a velocity of more than 13ft. per second in falling through the air, and a drop the seventy-fifth part of an inch in diameter can never acquire more than 8ft. speed per second, and a drop one-thousandth part of an inch could only attain a velocity of 2in. per second.

It should also be known that when rain drops fall through a long distance of, comparatively speaking, dry air, they naturally evaporate, and consequently the drops diminish in size as they descend, which is the reverse of that of falling into a warmer and yet moister region; and not unfrequently does it happen that large rain clouds will be giving water above our heads, and yet not a spot will reach the earth, but is entirely dissolved and taken up by the air, or even carried miles away by warm currents of dry air.

No doubt my reader has noticed in flat lying countries, especially in the spring time of year, rain clouds pouring out their grey bands of rain near the horizon with a kind of rag fringe of attenuated ends, which hang down below them, and towards the ground, but without touching.

I may mention that dew, mist, and fogs, which form a large portion of our water for springs, &c., are nothing more nor less than the air saturated with condensed vapour formed as follows:—

If the surface of the earth be hotter than the lower air, the aqueous vapour near the earth is chilled by the cold air, and so produces dew; but if the lower air be hotter than the earth, then the vapour given off from the surface of the earth quickly rises into the colder regions and becomes clouds. Such phenomena is well illustrated with steam, steam being invisible, but when it comes in contact with cold air it is immediately condensed into larger molecules, which, like the clouds, become visible. To prove that steam is invisible, look into the water gauge of a boiler, or at the spout of a boiling kettle, &c., from which steam is allowed to freely issue, you will not be able to discern the steam close to the spout of the kettle or pipe, nor within half an inch or so, and according to the state of the atmosphere into which it issues. And the rain and atmosphere is not at all unlike even to this simple experiment.

Evaporation.

For instance, in hot regions the evapor[illegible] than in the colder. The River Jordan is c[illegible] into the Dead Sea, which, notwithstan[illegible] evaporation at a level of more than [illegible] the Mediterranean. Taking the [illegible] evaporation from a free surface [illegible] equal to the rainfall. The eff[illegible]

air is to cause the vapour to be precipitated in the form of cloud, mist, or fog. A greater and more continued chill causes or brings rain, hail, or snow. While, however, in an open plain there is less rain at a considerable height above the ground than at the surface, somewhat different conditions prevail in mountainous districts, for the rainfall increases, as a rule, in ascending the slope of a mountain. The quantity of rainfall of any country is in the main dependent on the position of the mountain ranges and the prevailing direction of the winds. For instance, India, with its monsoons, affords a good example of this fact, the ghâts or mountains facing the winds from the sea being subjected to an abundant rainfall; while, on the other hand, Tibet is nearly rainless, the Himalaya mountains effectually acting as condensers to the vapour-bearing winds. In England, the annual rainfall, as I have said on pages 135 and 136, Vol. I., varies from about 140in. at Seathwaite, in Cumberland, to a little more than 20in. in some parts of Norfolk and Lincolnshire, but the annual variation is very great. The fluctuation of rainfall is marvellous, and scores have made it a complete study, and found that in any part of this country the wettest year would have a rainfall of nearly half as much again as the mean; the driest year would have one-third less than the mean; the driest two consecutive years would each have one-quarter less than the mean; and the driest three consecutive years would each have one-fifth less than the mean. It has been pointed out that there must, on high mountains, be an upper limit of the maximum amount of rain. The decrease of temperature, with increasing elevation, involved a decrease in the amount of vapour held in the air, and the maximum rainfall is, therefore, to be expected at the height at which, as a rule, condensation was first produced.

Floods.

In England the rapid melting of snow is a frequent and principal cause of floods, especially in districts consisting of porous soil, the surface of which had been hard frozen before the snow fell on it. The amount and quality of the water supply from a given amount of rain is most immediately connected with the geological character of the country in which the rain falls. If a tract of country existed of bare, impervious, unfissured rock, the surface being traversed by valleys conveying to one common outlet, the whole of the rain, less some small quantity carried off by evaporation, would be delivered by that outlet. If, instead of complete valley-systems, there happened to be depressed portions forming basins, lakes would be formed, which might be either permanent or temporary. If, instead of the rock being bare, there is a certain amount of superficial soil and vegetation, any moderate shower would be absorbed by the soil and plants, and but little water would reach the outlet. A few days of fine weather in summer would render the superficial soil again dry and absorbent, so that the water passing to the outlet might bear but a small proportion to the rain that fell; but in winter these proportions would be immediately increased. In the case of impervious but fissured rocks, the existence of the fissure would lead to results not materially differing from the presence of lake-basins within the area. Impervious rocks are mostly found in elevated ..ts of country, where the rainfall is usually great, and ..portion of the rainfall finding its way into streams must be large. In the Loch Katrine district, ..infall at the head of the loch was 103in. in ..alculated that [illegible] discharged from .. loss from [illegible] of 21in. .. the o[illegible] differ from that

which resulted from rain falling on impervious rock, as in dry seasons clay is fissured by contraction, and though practically impervious, it is by no means unabsorbent; but heavy clay lands are now artificially drained, and the surface does not become water-logged as formerly. Both in clay districts and those formed of impermeable rocks, it frequently happens that there are superficial patches of drift gravels or sands of an absorbent nature; these, after heavy rain, become charged with water, some of which is subsequently delivered at the lowest outfalls, forming land springs. Again, on permeable rocks there are occasionally patches of impermeable clay, such as the tertiary outliers on the chalk. Mr. De Rance has published a hydro-geological map of England, in which he has divided the character of the soil into the impermeable, the partially porous, the "supra-pervious," and the permeable. Roughly speaking, the western part of England and Wales consists of impermeable and partially porous rocks, and the eastern of the "supra-pervious" and the permeable. Many river-basins consist of two or more of these different kinds of soil, and the flow of water in them consequently varies much from time to time; in wet weather they are subject to floods. A large portion of England consists of more or less absorbent rock, underlying a still more absorbent superficial soil, and it is to this fact that the comparative permanent character of some rivers is due. Any moderate rain falling on an absorbent soil at once disappears from the surface and finds its way among the particles of the soil. The new red sandstone at Liverpool is found to absorb $\frac{1}{22}$nd of its own weight of water, of which about one-half will not drain away. In loose sand and chalk the absorption is from $\frac{1}{12}$th to $\frac{1}{5}$th of the weight, or at the rate of 2 galls. to the cubic foot. A cubic foot of oolites and limestones would absorb 10 to 14 pints of water. With continued rainfall, anything beyond what could be retained by capillary attraction, gradually gravitates downwards, until it arrives at a point where the rock is already charged with water. In the bottom of valleys with streams running along them, the saturated rock would be found near the surface, but the rain falling on hills might descend hundreds of feet before arriving at the point of saturation. Friction prevents the water under the hills escaping readily; otherwise the surface of the saturated rock would present nearly a dead level, and the rain would flow off at the lowest vent almost as quickly as it penetrated the ground. At Brighton the surface of the saturated portion of the chalk gradually slopes upwards as it recedes from the sea, this inclination being due to the frictional resistance opposed by the chalk to the passage of the water. The level of the outfall varies, but the sea is never able to penetrate any distance into the chalk, and the rainfall suffices to keep up an inclination seawards in the water-line in the chalk. The subterranean water-level in Hertfordshire, is influenced by the hills and valleys, the level of the water being mostly allied to these, though the inclination is much less in degree. In the middle chalk in Hertfordshire the slope is about 12ft. 6in. to a mile, in the lower white chalk about 19ft. 6in., and in some parts of Kent as much as 40ft. to the mile. After heavy rainfalls the inclinations are much steeper. Where the pumping from a well in porous rock is excessive, an inverted cone of depression is formed in the plane of saturation, the angle of which is determined by the amount of friction in the rock.

Bournes and Watercourses.

Water readily finds its way along layers of flints in the chalk, so that, in boring, an accession of water is obtained directly a layer of flint is traversed. From deep borings the water generally rises at a higher temperature than from

ordinary springs. The water from the artesian well at Grenelle, close to Paris (hereafter also to be spoken of), which is from a depth of 1,800ft., has a temperature of 82° Fahrenheit, being about 30° above the springs in the district. The water at the bottom of a boring 1,334ft. deep at Richmond has a temperature of 75½°. Where chalk is overlain by stiff clay, through which, however, it in places penetrated, swallow-holes are formed, and the rain falling on the impervious clay, forms streams, which make their way into such swallow-holes and disappear in the chalk; and this, too, is the origin of subterranean watercourses in limestone districts.

Percolation.

Experiments on the proportion of percolation through about 3ft. of soil to the rainfall on the surface were made by Dr. John Dalton, of Manchester, and Mr. Maurice, of Geneva, about the end of last century. The principle on which the experiments on percolation were carried out was much the same in all cases, and was described. Much had been done in this direction by Mr. Charles Greaves, Sir J. B. Lawes, and Dr. Gilbert. The two latter gentlemen had found that, for the ten years, 1871 to 1880, out of a mean rainfall of 31·451in., 14·040in. passed through 20in. of soil, and 13·241in. through 60in.; and that, out of 16·365in. of summer rain, only 4·111in. found its way through 60in. of soil; while in the winter there passed 9·130in. out of a rainfall of 15·086in. The late Mr. John Dickinson has the honour of being the first in this country to repeat the experiments of Dr. Dalton. His operations began in 1836; but new gauges were fixed at Nash Mills, Hemel Hempstead, Hertfordshire, in 1853, and observations have been continued ever since. Mr. Evans, of the same place and works, has arranged the results of thirty years' observations. The average showed that, out of a total annual rainfall of 27·843in., 6·519in. passed through 3ft. of soil, and 10·590in. through the same depth of chalk. The proportion of the percolation to the rainfall varied greatly from time to time, even for the same seasons, instances of which were given. It cannot be too often repeated that every gallon of water pumped and carried away from an absorbent district is so much abstracted from the flow of the streams of that district. In inland districts the streams formed an exact gauge of the excess of the rainfall over the water carried off by evaporation, and any artificial diminution of the water must affect the streams.

London Water Supply: How to obtain.

If the annual supply of 4in. of rain would, from every square mile of country, give a daily quantity of nearly 160,000 gall. of water, which, at 32 gall. per head per diem, it will suffice for a population of 3,000. A population of 4,000,000, like London, would, therefore, if supplied from deep wells in the chalk, absorb the total water supply of 800 square miles of country, or of an area one quarter larger than the county of Hertford, and the whole of the surface streams over this large area would, in dry years, disappear.

Mr. J. T. Harrison's scheme for obtaining water by means of tunnels in the chalk of the Thames valley merely means that all the water derived from the tunnels would either be intercepted on its way to the river, or filter into the tunnels from the bed of the river itself. The flow of the Thames below would be diminished by just the same *amount of water* as that abstracted by means of the tunnels.

I think that I have written sufficient about where we get our supply of water from, but it may strike some of my readers, as it did a sharp apprentice that stood with his mouth wide open, listening to one of my lectures on water supply. He called out, "Governor, where did the Israelites' cattle get their water from when in the waterless wilderness?" And although the question was a simple one, it required a lot of thinking about, in order that the question could be satisfactorily answered; yet, like all other things when known, it is as simple as yes or no. Here is the true explanation. Also see Town Water Supply.

Change of Climate and Water Supply in South-Western Asia.

How did the cattle of the Israelites subsist in the wilderness? Those who ask it do so on account of being unaware that the whole climate of South-Western Asia has changed during the last five thousand years. This change has been going on even in recent times. Zenobia, for example, was queen of Palmyra, and was defeated by the Romans; but the site of the ruins of Palmyra is now a howling wilderness, which obviously it could not have been when Palmyra was a populous metropolis. Nor is the case of Palmyra by any means an isolated one: ruins are constantly spoken of by travellers as found in waterless deserts; and the travellers not unfrequently attribute the desolation to some mysterious change which they suppose to have taken place in the soil. But the cause is, probably, only the lack of water; the climate has become drier; the soil has become dust, and the sand from sandy tracts has blown about through not being held together by moisture and by vegetation which could no longer grow on it when it became dry. Contemporary travellers, again, are never weary of praising the brilliancy of the climate of Egypt, and, indeed, of Lower Egypt, farther than which the majority of them do not penetrate. But by the ancients the climate of Egypt was considered to be the reverse of brilliant, and as late as the thirteenth century an Arabian geographer writes of it as dark and gloomy. The reason of this is easily intelligible. The whole country was anciently irrigated by canals leading from the Nile, whose waters were caught and evaporated instead of flowing in bulk uselessly to the Mediterranean; and, as before remarked, the annual evaporation of an immense mass of water must have rendered the air much more cloudy than it now is. The canals were allowed to become useless in the later misfortunes of Egypt, and whatever winds blow from Egypt are now dry instead of being moist. The same cause has been also operative in the valley of the Tigris and the Euphrates, and remains of these canals are still to be seen; but they have fallen into ruin, the waters of the two great rivers run uselessly into the Persian Gulf, the country is dried up, and the winds which blow from it are also dry. To this cause others have probably been added, but, taking it alone and by itself, it is pretty clear that it would be able to produce most important results. Not much is required to turn the scale, in a tropical or semi-tropical country, in favour of dryness; and when once the amount of vegetation begins to diminish through partial aridity, the diminution tends to be progressive, because plants and trees bring down rain and hold the moisture in the earth. The fewer of them there are, the less rain falls, and more of what does fall runs to waste; this produces a still further diminution of vegetation, which is followed by a further diminution in the rainfall; and so on, till a country which was once a jungle may become a waterless desert.

FIG. 771.

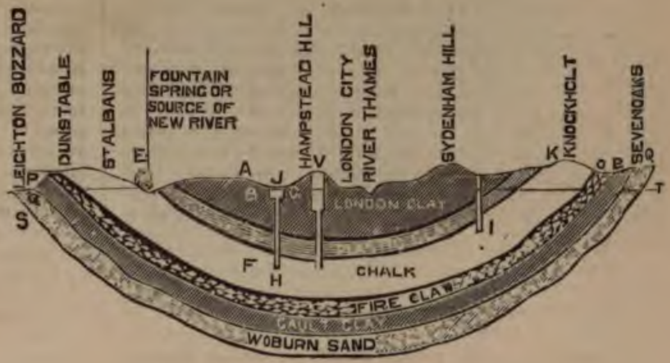


FIG. 772.

Wells.

After the foregoing it will be seen that the rain, snow, etc., which fall on the surface of the earth, will penetrate the ground, sand, gravel, and other porous substances, until they meet with some solid substance as rock, or some plastic substance as clay, or other impervious materials, and if not impounded or confined, the fluid will glide in a lateral direction until it finds some kind of pervious material, or some opening, such as a fissure or cleft in a rock, when it travels through the earth, often for scores of miles, until it finds a lower level, and will so supply wells or become the necessary spring. For an illustration of this, I will refer you to Fig. 771. At B, G, D, H, O, is the land whereupon the rain falls. Suppose it to be ordinary meadow land, with the ordinary loose soil and rock below, as at A. From A to opposite G it is of convex shape. Here a certain amount of the rain water will be held, and if a shaft, as at B, is sunk to this water level, we at once come across the spring, and the deeper you dig into this basin of course the more copious will the supply be. Now examine the shaft at H: this is sunk into the pebbles, having no clay or rock between it and the top of the chasm K. Here no water can be obtained, because it all filters, and drops into the chasm. By digging further you would, in the course of time, meet with what is not at all unknown to the well-sinker—"the drop," sometimes to his certain destruction, and other times to his great joy. This was the case with the boring rods of M. Mulot, when boring for the celebrated well of Grenelle in the Paris basin, of which I shall hereafter give fuller particulars. After boring for over 1,802ft., at last the boring rods and tools made a sudden drop of several yards, as from the bottom of the shaft H to the bottom of the chasm K, Fig. 771. But in the case of this well, nearly all materials above were impervious, and the water was impounded in such a manner, that on tapping it the water r--- to a considerable height above the surface. In Fig. 7 may be seen a water channel or passage; this is fr met with in mines, quarries, &c. Into this cha water drops or percolates from the nearest opening, such into a chasm. From P rock, which allows the into the chasm P. through the ea into it, wh dark spot, t where the s

Artesian Wells (London).

I will now give you some idea of our London artesian wells.

For this purpose refer to Fig. 772. A represents the surface of the earth, B the London clay, the top of which is according to the district, E is the plastic clay, F the chalk from whence we get our best water. It will be seen that these strata are of a curved form, their ends coming up to the surface, the plastic clay at E, and the chalk at St. Albans and Knockholt. The rain water falls upon the ends of the chalk at Dunstable, Knockholt, &c., &c., and is collected in the bed of the chalk at F, H. It cannot get away by reason of the impermeable strata of fire clay and gault clay, which in this case answer the same purpose as the rock in Fig. 771. The rain water is accumulated in the joints and crevices of the chalk, and will overflow at E on the line S, T, which is one of the sources of the water supplied by the New River Company, of which I shall again refer to further on in my town water supply. The deeper the well, of course the better the supply. If you want a better supply than your neighbours, you may at times get it by sinking deeper.

For instance, suppose the bottom of the sunk well J, G to be 10ft. below the water line S, T, here, if not otherwise interfered with, you will get 10ft. of water. But suppose the well V to be sunk 30ft. deep, and the pumps kept at work, which would keep the water level in well V below the bottom of the well J, then J will have to be sunk lower, more especially in some parts of the chalk, because these do not supply sufficient for the two wells; whilst in other parts you may sink two wells close together and then get a full supply of water, or it may be that one will get a good supply whilst the other will be dry.

I may here remark that the mere boring of a hole into the earth is not at all times sufficient to ensure a good chalk water supply, for in many places you may bore a well, and have to pass through sand, shingles, &c., h will require some kind of pipes to keep the hole from the sand, &c. In London well digging work e by the well sinker, but in many parts of the y the plumber has the management of such work. ow where we get the water from and one way to the bowels of the earth: and as this is a work I shall not be expected to go much into well e, therefore I shall only give you a general and recommend you to get a work subject.

Well Sinking.

Well sinking is simply the digging; and well steining is the lining of the excavated part with brickwork or cement, &c. (or at times cylinders of iron are used), which may be 4½in. to any thickness brickwork. [See Figs. 774, 815, 868, &c.] For instance, a loose ground will require every precaution to stein the work or sides of the well in a substantial manner, whilst in cases of hard excavating, such as through hard chalk or rock, the operation of steining can be dispensed with. Wells are generally of a circular form, and is the best shape to prevent the sides falling in, and of a suitable size for a man to work in comfortably. Sometimes the deeper they are to be sunk the larger they should be in diameter at the top, as in some cases the steining will require to be larger at top on account of the looseness of the surface soil. [See Fig. 774.] Of course, large wells require thicker steining than small ones. For instance, a well 5ft. in diameter through a stiff clay will only require a 4½in. steining, whereas one double this diameter will require a 9in. steining. Sometimes it is necessary to work the brickwork with cement, whilst at other times this is not required, the bricks being simply placed round the well as a kind of packing only. Sometimes, where land springs abound, it will be necessary to be very careful about the steining being puddled behind in order to keep out the land or surface water; or instead of puddled clay cement or concrete may be employed, or even iron cylinders. The bricks employed for the steining should be best stocks, hard, well burnt, and of good shape; Malm paviors in many cases should be used.

The old method of steining, and even that which is now practised in many parts, is very simple. It is done by employing a wood curb or cylinder, Fig. 773, about 6ft. long by 4ft. diameter, made out of, say, 1in. floor boards, the staves being preferably nailed close together, viz., when the ground is bad or loose; at other times it is made with the staves or boards kept an inch or so apart. Now, the earth being removed from the bottom and the curb being

FIG. 773.

WELL STEINING CURB.

loaded with bricks all round the inside, also on the top, it, with this superstructure or weight, as the earth is dug from under the curb below, sinks gradually down, and so the work proceeds, care being taken not to dig more away from one side than another, or the well will not be sunk with plumb walls. This goes on until the curb will sink no further, owing to the earth swelling, or pressing against the sides of the curb, in which case a new curb often must be employed smaller than the first (see Fig. 774), J, K being the top curb or steining above the smaller. Sometimes, where the ground below is loose, it is necessary to have an extra thickness below, as at E, F, Fig. 878. The steining, when the wood curb is not employed, is executed by working the bricks partly dry and partly with cement, the latter simply being from three to four courses of brickwork in every 5ft. or 10ft. length, or, in other words, at intervals between the portions of dry brick work, which must be regulated by the nature of the ground (see Fig. 774), A being the brickwork in cement, and B the portion to be filled up between the rings of cement work, as from A to D. The curb thus built should be kept well back against the earthwork, as the friction acts as a kind of support to the bricks, and so prevents them slipping; the latter being often prevented by artificial means, such as by the use of wedges, or by the use of cement at the back of the brickwork. Of course, such steining can only be done in firm ground, such as clay, &c., sandy and loose ground must be worked with a curb, &c.; or it can be worked without a curb by using cement all up, viz., as the last described method. Sometimes cast iron curbs are employed where the land springs must be kept out, or where the ground is loose or otherwise bad.

Steining.

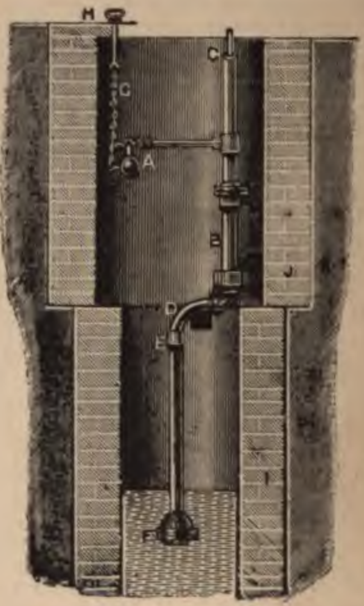


FIG. 774.

The method of laying the bricks for well steining is generally lengthways, breaking the joints of each layer as in ordinary brickwork, but sometimes the bricks are laid endways, viz., the end of the bricks pointing towards the centre of the well, but this is not so good a plan as the former. Suppose, in both cases, the bricks to be laid in cement, the bricks laid lengthways press with their ends upon wedges of cement, whilst those laid endways press upon their sides upon the cement, and the chances are that the bricks move endways tow[illegible]e centre [illegible] the well.

Stages should be worked every 1[illegible] or sho[illegible] as at Figs. 875 and 878, to fix the [illegible]pporti[illegible] the pipes, &c.

History of Well Boring.

The Chinese hold the oldest record of well boring. Thousands of bored wells are to be found in the province of Ou-Tong-Kiao. These wells are from 1,500ft. to 2,000ft. deep, and from 5in. to 6in. bore. They are bored by first digging down a convenient depth, and securing the rain water, land springs, &c., from getting into the well. Then they proceed much about the same as the top man at the lever in Fig. 775, but instead of a chain and augers, the Chinese use a rope with a kind of heavy drill shaped weight fixed to the end of it. Having started this weighted drill arrangement a yard or so, the man at the end of the lever begins to lift it up, which, by the torsion of the rope, causes the weight and drill to work round, then he lets it drop, and so, by a continual lifting and dropping the well is bored, sometimes taking four to six years' constant work to complete. The weight is about 4 cwts.

The ground for foundations of buildings, &c., is often bored, as was that of St. Paul's, London; in fact, this is the first mention of earth boring in England. Wells are also bored for mineral oils.

Gas Wells.

This appears strange to some people; but there are many such wells near Pittsburgh. The Burns gas well, thirty-five miles from Pittsburgh, sends out 1,000,000 cubic feet of gas per hour, weighing 58¾ tons. This gas contains 80 per cent. of carbon and 20 per cent. of hydrogen, and it has the enormous pressure of 200lbs. per square inch. This supply is therefore 1,408 tons per day, or 1,126 tons of carbon and 282 tons of hydrogen, equal to 1,250 tons of anthracite coal, or sufficient to smelt ore enough to make 700 tons of pig iron.

Deepest Bore Hole in the World.

Perhaps the deepest bore hole known is at Sperenberg, about twenty-four miles south of Berlin. In 1867 a bore hole, 16in. or so in diameter, was begun in the gypsum rock, and sunk 273ft., when antrydric of lime was found, but on boring another 5ft. or so rock salt was met, which, on boring to a depth of 284ft. from the surface, was found to be quite pure. This bore hole was continued till the end of 1868, when it reached 956ft., with a diameter of 12½in., and three sets of iron tubes had been inserted. Boring again commenced in 1869, by steam power, and at the end of the year the well reached a depth of 2,527ft., and the boring being continued to the end of 1870, the well was 3,479ft. deep, and at the middle of the year 1871 it was 4,170 feet deep. The strata of rock salt here is 3,768ft. (Rhenish) deep.

The Serpentine Well, Kensington Gardens.

It may be of interest to some of my London readers to know that the splendid Serpentine lake contains one of the purest supplies of water in the world. It is first sunk 203ft. deep, and with the following thicknesses of brickwork—

9in.	25ft.
4½in.	67ft.
9in.	5ft.
[illegible]in.	10ft.
	5ft.
	91ft.
Total	203ft.

The remainder of the well is lined with iron cylinders, having a diameter of 4ft. 6in. These cylinders come to within 173ft. of the surface. The water rises to within 105ft. of the surface.

These are the substances met with—

Depth from Surface.	Plastic Clay.	Thickness.	
122ft.	Made ground and London Clay	122ft.	Reading Series.
127ft.	Shells and Sand	5ft.	
137ft.	Mottled Clay	10ft.	
141ft.	Sand and Pebbles	4ft.	Thanet Sand Series.
145ft.	Mottled Clay, Green Sand, and Pebbles	4ft.	
149ft.	Green coloured Sand and Pebbles	4ft.	
152ft.	Green coloured Sand	3ft.	
196ft.	Grey Sand	44ft.	
196½ft.	Layer of Flints	½ft.	
298½ft.	Chalk	102ft.	
	Total	298½ft.	

This well is said to be 321ft. deep, but how they make it I know not.

Well Boring and Artesian Well Tubes.

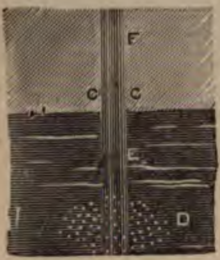
Many systems of boring have been invented, and many are practised to this day, and although the principles are extremely simple, yet the work requires skill and care. After sinking the well to the depth to which you think your water will rise, you can commence boring by any of the following means. Boring with a rope is called the Chinese system. Here the borer is suspended by a rope, which, when the tool is worked vertically up and down, imparts by its torsion a circular motion to the tool, such tool being surrounded by an iron tube, the collected earth in the circular space being brought to the surface in various ways. I think very little of the above method.

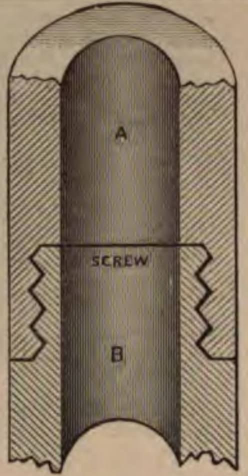
The ordinary plan of boring is shown at Fig. 775, viz., with an auger as shown at A, Fig. 777, which differs according to the nature of the ground. These augers are generally worked with rods of different lengths from 8ft. to 12ft., a circular motion being given with a lever by one or two men walking round in a circle as illustrated at A, Fig. 775, the boring tools being partially suspended by a lever, or otherwise, as shown at L, E, F.

Well Tubes.

As soon as the hole is bored to a reasonable depth, or through the clay, a tube of iron or of copper, *perforated* at the bottom, if the spring is in the sand, is let down into the bore hole to keep out the sides, or to prevent the sand, &c., from getting into the bore hole, thereby preventing the bore hole becoming choked up. As shown at Tube, Fig. 775, these pipes are best screwed together, and must be smooth on their outer sides so as to allow them to pass through the bore hole without obstruction, and as shown at Screw, Fig. 775. Sometimes two lots of tubes are used, one to bring up the sand spring water, and the other continued into the chalk for the chalk springs water. See the Double Tube Well, Fig. 776.

Of course, the latter pipe is of a smaller bore, and continued beyond the sand spring level. Such a well is in action at St. Owen, in France. See Fig. 776.





TUBE.

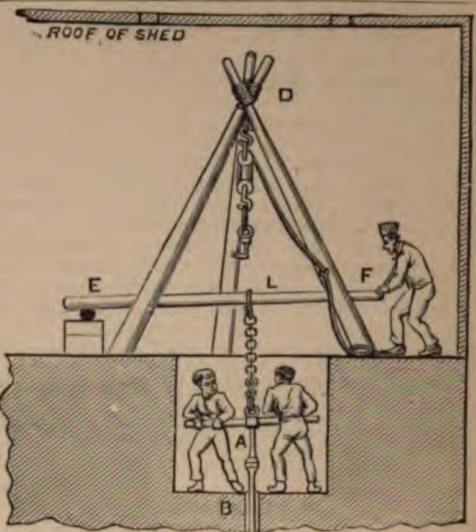


Fig. 775.

The Kissingen Brine Spring.

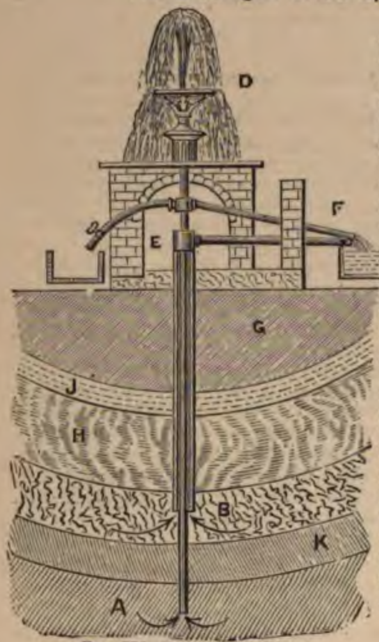


Fig. 776—St. Owen's Well.

This St. Owen well is very extraordinary, and as can be seen gives a supply of water to the surface from two water bearing stratas at once; the stronger force comes from the lower at A, whilst B gives a supply at a lower pressure. You may often reverse this and drain a land spring into a deep well spring as follows. Suppose a land spring to be on Sydenham Hill, see Fig. 772. Bore a hole into the bottom of the well to the chalk, and you will soon find a dry land spring well. See Brine Well.

Well Boring Tools.

The well boring tools generally in use are shown at Fig. 777. Augers are used for clay or other loose soils, whilst chisels and such like are used for the more dense material, and the loose particles chipped from the rock, &c., are picked up and raised to the surface with an auger, having a kind of valve in its lower part, like that shown at B, Fig. 777, and known as a miser.

Should the rods W, Y, Fig. 777, of the boring tools get broken in the bore hole, they can be recovered with such tools as are shown at F, G, J, &c., Fig. 777. The tubes are sometimes lowered with a tool such as is shown at H, Fig. 777. Of course, there are many other tools made for *special purposes, such* as for cutting the bore hole round the *outsides only, and by bringing up the stone,* &c., in the *shape of a core from 3ft. to 4ft. long; such a tool* may be seen at I, Fig. 777, and I may add that different well borers have different tools according to fancy, but the tools here shown serve to give the reader a general insight into the work. I shall conclude the account of well boring by giving my readers an account of a few wells which I have been connected with, viz., two wells which supply the fountains at Trafalgar Square, Charing Cross, London, and an account of the artesian well at Grenelle, Paris.

Fig. 777.

The artesian wells at Trafalgar Square are connected by a 6ft. diameter driftway. The one in front of the National Gallery is sunk about 180ft. deep, and is 4 or 6in. in diameter; the other is in Orange Street, about the same depth, but 6ft. in diameter, and with the driftway will at times contain 122,000 gals. At the bottom of these wells the boring commenced, and the one in the front of the National Gallery is 395ft. deep to the surface, whilst the one in Orange Street is only about 300ft. to the surface.

The following is a section of the two wells:—

Orange Street Well.

Dug	Ft.
Made ground	15
Gravel	5
Loam and Gravel	10
London Clay	145
Thin layer of Shells	—
Plastic Clay	30
Gravel and Stones	10
Green Sand	[illegible]
Bored Chalk	[illegible]

T

WELL IN FRONT OF THE NATIONAL GALLERY.

Dug	Ft.
Made Ground	9
Gravel	5
Shifting Sand	7
Gravel	2
London Clay	142
Thin Layer of Shells	—
Plastic Clay	30
Green Sand, Pebbles, &c.	11
Green Sand	42
Bored Chalk	147
Total	395

Artesian well at Grenelle, Paris. This well was bored for the purpose of supplying the abattoir (slaughter houses) by M. Mulot. After eight years' labour, with many accidents, on the 26th February, 1841, M. Mulot reached a depth of 1,802ft., and was crowned with the success of his great undertaking, who for yearshad been sneered at by the incredulous. The numerous difficulties attending this work were of the most trying character, arising from the breaking of the rods and such like. Fancy, after boring 1,250ft., 270ft. of the rods falling to the bottom, breaking into several pieces, and then having to be fished up again with a screw tap; here was fifteen months' trouble and labour. After this, in the year 1840, a chisel fell to the bottom and buried itself in the solid chalk. In this case it was necessary to clear all round this tool and to grapple it up as before. After this a shell fell to the bottom, which had to be pushed on one side in order to continue the boring. This done, and after another three months' work, he had cut through the following substances :—

	Ft.
Drift Gravel	33
Sand, Clay, Lignites, and replacing the Calcaire Grossier	100
Fragments of Chalk in a species of Clay	16½
Chalk	1,378
Chalk Marl	88½
Gault, Clay, and Green Sand	186
Total	1,802

And here at the depth of 1,802ft. a rush of water was heard, and in next to no time it was seen to flow at the enormous rate of 800,000 gallons per day, and to a height of 122ft. above the level of the earth at a constant temperature of 81·81° Fah. The cost of this well was 400,000 francs, or £16,000.

I think the largest, though not the deepest, artesian well is at Passy, in Paris. This well is sunk through the chalk into the green sand, finishing with 2ft. in the bore, and is 1,913ft. deep; it was six years and nine months about, and yields 3,795,000 gallons per day, the cost of which was £40,000. It was lined with solid masonry to a depth of 150ft., then iron tubing was fixed 1,804ft. from the surface, and below this was fixed a length of copper tube, of course, pierced with holes.

Brine Well at Kissingen.

Perhaps the deepest well bored is that at Kissingen, in Bavaria, Germany. This is a brine well, began in the year 1836, and in 1850 water was reached at a depth of 1,878ft.; -r this its depth was increased to the rock salt at a of 2,000ft. The water issues at the rate of 100 cubic minute. The ejecting force is supposed to come from a subterraneous atmosphere of carbonic acid gas, pressing with a force equal to sixty atmospheres. The construction of this tube well is not like those before explained, inasmuch as these tubes are concentric, water rising between an outer and middle tube (similar to that shown at Fig. 776). The water passes down between the middle and outer tubes and into the rock salt, where it becomes saturated, and then it is raised up the middle tube to the top of the well as brine.

I may add that sometimes the bore hole becomes blocked with sand, &c. As early as the year 1794 we have records of these sand blocking troubles in well boring. A Mr. Valliamy, of Norlands, Tottenham, near London, sunk a well 236ft. deep; fearing to sink further, he commenced a double thickness of steining, reaching 6ft. from the bottom upwards, and began to bore with a 5½in. auger, and a copper pipe was driven down the bore hole to a depth of 24ft., at which depth the borer pierced through the rock into the water *with a sudden drop.* [See Fig. 771, at H.] Here a mixture of sand and water instantly rushed up the copper tube, and in eleven minutes there was 124ft. of water in the well, and in one hour and twenty minutes the water rose to within 17ft. of the surface.

The next day water was drawn out to about 5ft., but in a short time it again rose to within 17ft. of the surface. A sound line was then let down in order to try its depth, when it was discovered that the well was not so deep by 96ft. The cause was ascertained, and sand was the result. After a few days the water was again lowered 10ft., but it did not rise again by at least one foot as before. This was again and again repeated, and each time the water did not rise so high by about one foot. At last the sand was reached, and on continuing to bail out the water the sand showed itself quite dry and hard. This sand was then again dug out to about 60ft. At this point the water instantly again rushed up the copper tube with great force, and almost suffocated the man who had been engaged in the digging, and in a short time the water rose again to within 17ft. of the surface, but on letting down the sounding line the well was as before filled with sand to about the same level. The next thing was to set to with iron buckets and draw up the sand before it could get hard, and by keeping constantly at this the water rose in the well, and at last the difficulty was overcome, and a constant overflowing took place, showing that when the sand was there it kept the water down.

COST OF DIGGING AND BORING WELLS.

Rates accepted for sinking a well in Caledonian Road, London.

			£	s.	d.
Sinking a 6ft. Shaft, the first 30ft.			£67	10	0
Do.	do.	second 30ft.	57	0	0
Do.	do.	third 30ft.	58	10	0
Do.	do.	fourth 30ft.	60	10	0
Do.	do.	fifth 30ft.	61	10	0
Do.	do.	sixth 30ft.	67	10	0
Boring per foot a 10½in. hole... ...			2	2	0
Do.	do.	7½in. in chalk ...	1	7	6
For Perforated Copper Pipes fixed per foot			0	10	2

Of course, the top part of the above shaft was sunk much wider than 6ft., viz., to 9ft. 6in. diameter, to allow for the 9in. brickwork and 12in. of puddle, this was carried down to a depth of 10ft., and after this the excavation was only 7ft. 6in. in diameter and 5ft. deep, and the back steining only of half a brick in thickness, completed with cement. Then similar 5ft. excavations were made in succession, and the back steining only in each case completed, until the London blue clay was reached at a depth of 30ft. The inner steining was then carried up in Portland cement and well grouted to the back steining. Of course,

the inner steining was brought up to the face of the first portion of the projecting 9in. brickwork, so as to underpin the first portion of this 9in. brickwork which had at first been completed; thus the land springs were effectually shut out. After this, the work went on as per price and specification, to a depth of 150ft. Here some loose moist dark sand was met, which would not afford a sufficient foundation for the brickwork. The water could not be pumped out or the sand would spew up, and here cast iron cylinders were used, 5ft. in diameter and 1in. thick for the steining. The specification for supplying the cylinders in lieu of brick steining was then provided for and also to suspend the present brick steining by iron rods from the bottom, up the shaft, to cross beams at the top of well, and to excavate and fix the cast iron curb with internal flanges, and to properly pack and bolt the same together with iron cement, and to carry them down through the upper sand and drive the lower end firmly into the clay, and to concrete behind the upper cylinder with gravel and cement, so as to form a footing for the lower steining and for stopping out the water, and to provide all required materials at £7 2s. 0d. per lineal foot. I have said that the steining had to be supported from falling into the sand below. This was done by fixing supports of elm under the brickwork, and supporting it with four 1¼in. rods to two strong beams across the mouth of the well (sometimes these iron curbs are put together in three pieces, viz., in sections, in order to get them down the well). To keep the cylinders plumb four 7in. by 2½in. battens were used, 20ft. long, these were fixed to the lower part of the steining, which, when fixed, formed a frame for the cylinders to slide through. The first cylinder was now lowered to the bottom, and then properly put together, and then another was added on the top of the one just lowered, and the joints on the flanges made good, and the others were added, which made up 30ft. of cast iron curbing before the excavation was proceeded with. In this way the true direction of the cylinders was maintained, and the mass descended into its place as the excavating or, rather, boring was carried on. This boring was done with a 4ft. 10in. auger, which was made to work just within the cylinders. Here each time the auger was withdrawn the cylinders would settle down on an average of about 2in. at each drawing-up of the auger. The stratum of sand was about 20ft. deep, which, had it been a quicksand stratum, the difficulty would not have been greater. When the stratum of sand was cut through hard mottled clay was met with, where the cylinders were with a heavy dolly firmly bedded, which prevented the sand water forcing its way into the well. Now the water, which had stood above the top of the sand, was pumped out, and the well remained dry, when boring commenced with a 10½in. auger (instead of the 12in., which was originally mentioned in the specification) and carried forward to the chalk. After this an 8in. pipe was fixed, and left standing 6ft. up into the well. This well yielded about 800 gallons per hour, and the following is a section of the well:—

Section.	Ft.
Yellow clay and gravel	30
Blue clay	100
Mottled clay	19
Dark loamy sand and water	18
Hard mottled clay and sand without water	17
Dark sand with little water	34
Hard flint	1
Chalk	151
Total depth	370

	Ft.
Distance of bottom of brick shaft to surface ...	153
Distance from top of iron cylinder to surface ...	139
Distance from bottom of iron cylinder to surface	170
Distance from bottom of iron piping to surface...	230
Distance from top of copper piping to surface ...	220
Distance from bottom of copper piping to surface	259

When boring through chalk with the auger, the sides of the chalk necessarily become hardened, and if it is possible to pump out the water as fast as it can run into the well, it will have the beneficial effect of freeing the side of the hole, and thus more water will be likely to percolate through the sides of the bore hole.

Windlasses and Buckets.

Thousands of years ago the Romans used the windlass for raising buckets of water from wells. The simple windlass is shown at Fig. 815, and in the present age is too well known to require explanation. I shall therefore proceed to Fig. 778, which is an engraving of Warner's

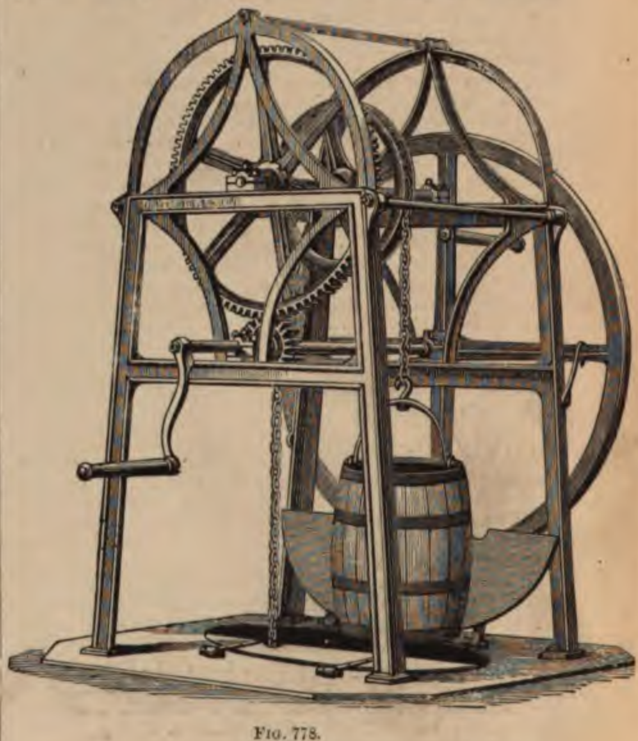


FIG. 778.

improved well windlass, with well cover complete. This modification of the windlass by cogwheels is for the simple purpose of gaining power, which were also well known to the Greeks and Romans, and even the Pompeians employed cogwheels and pinions. This style of raising water from deep wells is no doubt as simple a method as can be devised, and a method which will no doubt be continued until doomsday. No doubt the above machine is as perfect a windlass as ever can be designed, its mechanical parts being that of perfection.

Hot Springs.

The temperature of water from wells seems to increase at the rate of about 10·7 for every 100ft. below the limit of the constant temperature.

Hot springs are to be found in many parts of the globe, especially in volcanic countries, and a few exist with equal vigour where the ground is not subjected to internal commotion, and which may be accounted for through some local dislocation of strata, &c. The deepest springs have the greatest amount of heat, and will often gush out bubbling and boiling torrents, full of mineral and gaseous ingredients, such as salts, iron, bitumen, &c.

The spring which supplies the King's Bath, at Bath, has a temperature of 117° Fah., whilst those of Orense, in Gallicia, have a temperature of 180°.

We will now proceed to that which is more interesting to the plumber, viz., his pump work for Water Work.

PUMPS.

The pump is a hydraulic machine for raising water by means of atmospheric pressure, or by otherwise lifting or forcing it with a bucket, piston, or equivalent means. These machines are very wonderful to people who observe their action for the first time, and many a man has lost his head over these simple machines. Nearly all think they can get something new out of them, but no use, nothing fresh is to be found—clack and piston, rope, fan, bucket, ram, screw, air or steam is all the go and will be. It is very uncertain by whom or when it was invented. Some ascribe it to Ctesibius, of Alexandria, 224 B.C., whilst others ascribe it to Danaus. We have, however, very good reasons for believing that the pump was known to the ancient Egyptians. Among some of the modern interesting discoveries in the Egyptian monuments were bellows, which must have been worked with clacks, sculptured in the tomb of Thebes, and which bear the name of Thothmes III., a Pharaoh, and contemporary with Moses. Then Herodotus (Laurent's 2nd Edition, Vol. I., page 34, Clio I. 68) writes about the astonished Lichas, whose wonder was aroused at the blacksmith's forge, "Seeing the smith's two bellows, he inferred they were the two winds."

The two bellows were for the purpose of giving a continuous blast, as our double acting pumps. For my part, I believe that pumps used for water have been known at least 3,000 years.

Tree Pumps.

The old method of making and boring the ancient tree pumps, which to this day is much practised in the West of England, &c., may interest many of my readers. For this

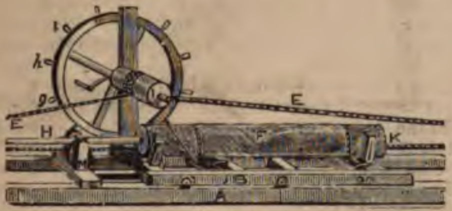


FIG. 779.

refer to the perambulator or frame, Fig. 779. It is from the practical work of G. Gregory, D.D., 1807, and is a correct drawing of a frame much used by my late Uncle ...s. well sinker, &c., of St. John's, Worcester, and ... wooden and other pumps are to be seen in ...aces about that and the adjoining counties. ...n constant use for over fifty years, and I ...e frame is still used by the sons of the above, who are now living in Herefordshire, where wooden pumps are also very well known.

This kind of carriage frame was also used for making the stone water-pipes, many of which may to this day be seen in the yard of the West Middlesex Pumping Engine Station at Hammersmith.

The method of boring the above trees will be plain. The auger rods H are generally, when at work, as in this case, so far as regards lateral or reciprocating motion, a fixture, although made to run upon the grooved wheel M, and the tree F K made to move upon the carriage or frame B, which travels upon the V-shaped runner-wheels in a V-shaped groove backwards and forwards. Such motion is given to the carriage from the wheel *g h*, and from there to the axle and cord E E, which passes over pulleys at the end of the lower frame, and back to the top frame, as shown at D and K. Of course, it will easily be seen that reciprocating motion may be given to the auger rods, as also to the top frame, and that, under the circumstances, the rods or frame must move in a true straight line with each other, and if the auger rods are made to run upon grooved wheels or runners in a fixed straight line with the centre of the tree, it follows that the tree must be bored truly throughout. At times the boring is commenced by first boring a small hole with an ordinary bit auger, after which a different sized and taper bit is used to enlarge the bore. Of course, as the boring proceeds, the tree is worked backwards and forwards to clear the borings or chips from the bore. In the above carriage frame, water, steam, or horse power may be used.

Some pipe-borers and well sinkers do not use a carriage frame, but simply fix the tree in an oblique direction, so that the weight of the boring rods will force the auger forward. They use "straddle struts" for the support of the boring rods; but this method requires much practice for good work, as the pipe is apt to be bored out of the true line or centre of the tree. Of course, this kind of

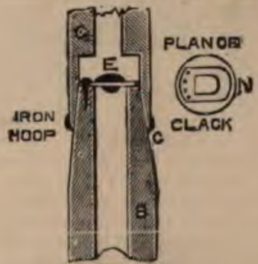


FIG. 780.

boring is only done by hand. The ends are shaped to fit into each other by means of a cone-shaped inside and outside cutter, or otherwise, and in such a manner that when the two are put together they *fit exactly*, as shown at Fig. 780, or if the fit be not perfect, rosin, cement, and tow may be employed.

The tree pumps are made of elm and oak—the latter is the better. Elder is also used.

When oak is used, for the first two or three months the water has a very nauseous taste, owing to the iron stain getting into it. Many a score times have I had to pump wells dry to rid them of this kind of water, but after they are once right such pumps are by far the best, in a sanitary point of view.

Wells should be properly ventilated when wood pumps are used to prevent the wood becoming mildewed, which sets up a serious kind of rot in the wood work, especially in soft wood, such as deal.

When the tree pump is bored too green, and fixed exposed to the sun and wind, it will split and crack, sometimes with cracks as much as 18in. long and ½in. wide. When such is the case, and you are called in to repair same,

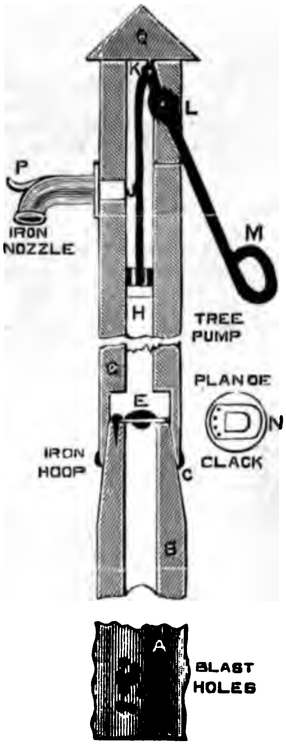


FIG. 781.

you must first dry the place, then paint it, and with a good putty-knife fill the crack with stiff red and white lead, plastering it well over the crack; then get a piece of sheet lead long enough for the crack and about 2in. wider, and with some 1in. clout nails nail the lead over the crack. This is known as pump-stopping, and is one of the first jobs the plumber's apprentice has to do in my part of the country.

It may be asked, why wooden pumps still continue to be made. The answer is that in many parts of the country leaden pipes are objected to on account of the material; and, for my part, I say that I prefer wood or stone, especially for some kinds of water.

For the fixing of the tree pump, see Fig. 781. A is the *bottom tree, which rests upon the bottom* of the well; the holes shown at A are the blast holes leading to the bored part. At C is the cone joint, made watertight. Upon the upper end of the tree, as at E, is fixed the clack or lower valve, which in this case is nailed in the top part of the bottom tree. The wood-seating or face part of the valve requires to be nicely faced true, so that the leather may shut down fairly upon its seating, in order to prevent the water running back into the bottom. There are many different methods of forming these clacks or valves, which will be seen throughout this work (see Figs. 782, 783, 784, 785, 786, 787, 789, 790, 791, 792, 793, 794, 795, 796, 798, 799, 820, and 823, &c.), but the one here shown at E, Fig. 781, is the oldest (known as the bellows clack; the name clack is taken from the peculiar noise which the bellows clack makes), and is still in use in many parts of the West of England. The great objection to them is, that whenever the leather is worn out, the top part, or tree, has to be lifted—not at all a pleasant job to do. When this top is off, simply with a cold chisel knock out the clout nails F, and take off the clack; but do not damage the face or seating of the valve. Next, with a suitable sized piece of good tanned sole leather, ¼in. or more in thickness, with all the fleshy part ground off, which is done by rubbing it with water upon a piece of sandstone, or other such like

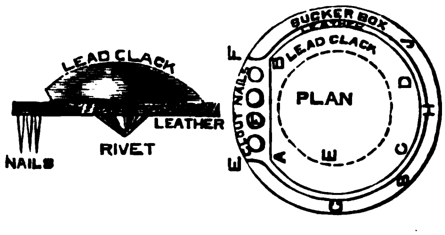


FIG. 782. FIG. 783.

surface, until the fleshy part is all worn off, make the clack as shown at Figs. 782 and 783; but before you can do so, you will require the lead clack, which is made as follows:—

Lead Clacks.

These clacks are cast in a two-sided mould (see Figs. 24 and 26, Vol. I., and for a full size clack, see Fig. 25). C is the clack; *rivet* is the part which holds the clack upon the leather; also see *rivet*, Fig. 782, which illustrates the rivet turned over the leather. For a plan of this clack, see A, B, C, D, Fig. 783.

Having the clack cast, cut the leather to the size of your clack seating, and rivet the clack on as shown at Fig. 782; then, in the case of the tree pump, Fig. 781, it must be nailed on the seating formed on the top of the bottom tree, great care being taken not to let the rivet be too much spread so as to prevent the leather from shutting down fair over the whole of the seating. Also, see that the leather is not too large to work up against the barrel of the pump. There should be a clear space of ¼in. all round, except where the nails come at clout nails, Fig. 783.

Pump Buckets, "Sucker Boxes," and F

We have seen how to fix the leathered clack fashioned wood ... er meth

be seen, as, for example, the wood sucker box, H, Fig. 784. This box can be used with the tree pump or otherwise, and is firstly leathered in the following manner:—Cut a piece of leather the shape of E, F, G, H, J, Fig. 783, then lay it over the hole in the box, and with a scriber or pencil from below, mark the leather all round the hole; lift the leather off, and prick the centre of the hole; next cut the hole for the rivet, but let it fit middling well. Then place the lead

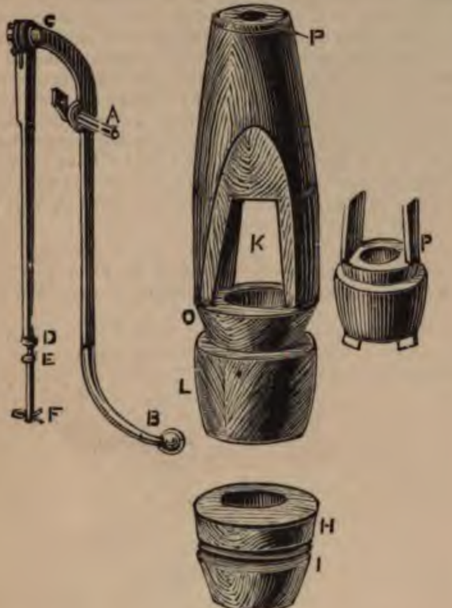


Fig. 784.

clack upon the outside part of the leather, and with the rivet through, place the back of the lead clack upon something hard, such as an anvil, iron weight, or large stone, and turn the rivet nice and true, as shown at Fig. 782. The rivet, if properly turned, will expand, and so fit the leather tightly. *N.B.—Always put the flesh side of the leather downwards to fit over the seating, or, in other words, with the grain or smooth side upwards. All bucket leathers have the flesh side fixed to rub against the barrel.* Having turned the rivet, next take a few good clout nails, for 2½in. and 3in. suckers ¾in. long, and with a fine bradawl bore the holes through the leather, but not into the wood, then nail the leather on to the sucker box, as shown at Fig. 783, and at F, Fig. 785. Also see Fig. 799.

Towing or Cementing "Sucker Boxes."

Next in order is the fixing the tow round the sucker box: this is very simply done, but requiring great care. It is done as follows:—Take a handful of tow, spun yarn, or flax, the longer the better, and bring the ends to points as though you were going to thread the eye of a needle, now wrap it nice and true but tight round the centre of the box, as at A, Fig. 785. Let it bulge in the centre shown, and with some fine twine tie it round. See your tow is not ragged or loose, nor too large or to enter the pump barrel, nor too small so as to useless.

Pump Hooks.

Now you require a pump hook. This is well illustrated at Figs. 8 and 9, Vol. I. H is the taper screw for screwing into the lead clack, as shown at F, Fig. 785. A, B, C, E, F, Figs. 8 and 9, illustrate the sucker hook, the end of which is passed through the hole in the sucker box, as when in the act of setting or drawing the sucker box.

Sucker Boxes (Fitting or Setting).

Now let us proceed to fix the sucker box into the pump barrel, as at A, E, Fig. 786. First throw a pailful of clean water down the pump to wash out all grit, &c., from the barrel; then take a small ladleful of mutton suet and make it boiling hot; place the sucker box, Fig. 785, upon the floor, and hold it there between the feet. Now take the sucker hook and screw it into the top of the clack, not too far, but just sufficient to carry it. Be careful not to lean too much on one side with the "sucker hook" when screwing the screw into the clack, or the box will overturn, and the chances are that the point of the screw will break or run into your foot. Now take the sucker hook and sucker in your left hand, and the hot suet in your right hand, and pour it over the tow, at the same time turning the "sucker box" round to prevent the fat running off the tow, *but keep the fat off the leather and face of the clack.* When you have poured in as much suet as the hemp will absorb, turn the sucker downwards and carefully put it into its place, as shown at A, Fig. 786; then press it down; this will prevent the box turning round; now quickly unscrew the pump hook, pull it out, turn the

Fig. 785.

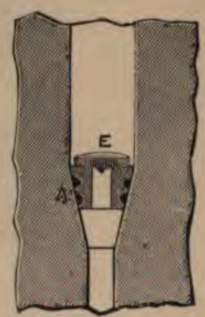


Fig. 786.

hook, and with the flat part A, Fig. 9, knock the sucker box down with, say, three sharp blows; this will set the sucker box, whilst the fat or cement is hot, and the pump is ready for the putting in of the bucket.

There are other kinds of sucker boxes (see B, A, C, Fig. 787). B is a brass sucker box with lifting spur or bow for the pump hook. A is the same kind of thing, but with different grooves.

Long Spindle Valves.

At G may be seen a different kind of "sucker valve" or box; it differs from the others by reason of its having the spindle E, which works through a guide within the

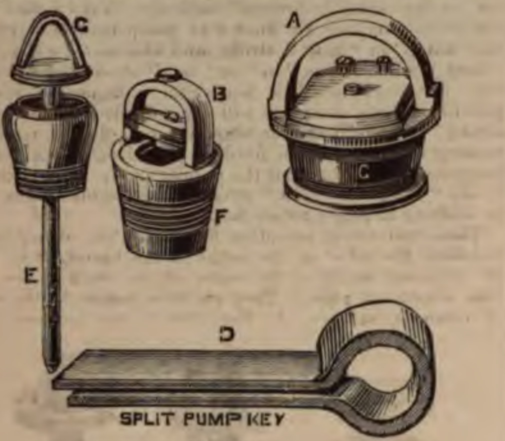


Fig. 787.

box; these valves are sometimes ground in, at other times leathered. When the latter method is adopted care should be taken to make the seating flat and wide, especially for very deep well pumps. These seatings should be at least ½in. wide, which prevents the leather getting out of shape by the pressure of the water. There is also

Fig. 788

another advantage in using these "sucker boxes"; it is that they may be cemented into the cone of the barrel, or *soldered*. When the latter is done, it is generally in the manner as shown at E, F, Fig. 788, and as follows:—First open the end of the suction pipe, as at A, wide enough to admit the valve A, then tin the valve and wipe a taft-joint as shown at E; next prepare the foot of the barrel as shown, and wipe the joint Q, F, but take care not to melt the solder on the inside. The proper way to do this is to wipe the inner joint with a coarser solder than the outer joint, the former of which will require a greater heat to melt it. Of course, the spindle can be readily hooked up by what is called a short hook (see the dotted lines, A, B, Fig. 8), out of the barrel when required for repairs, or these valves may be hooked up or set with a hook attached to a piece of strong string, especially in deep wells.

When selecting these valves see that the spindle is long enough, and that the bridge is well open cone-shaped to allow the end of the spindle to drop easily into the bridge. Although these valves are very good and handy, there is an objection to their use in some pumps unless judiciously selected, viz., large enough in the water way they should be twice the area of the pipes. If the lift is too great, the valve, when the pump is worked quickly, jumps too high, as much as 6in. to 7in., and during its descent allows the water to back, thereby to a certain degree spoiling the useful effect of the stroke of the pump, which is not so much the case with the clack valve B, Fig. 787.

Chemical Works, Valves, and Pumps.—Perreau's Rubber Cone Valves and Bucket.

These valves are illustrated at Figs. 789 and 790. They are made of indiarubber, and after the manner of the natural valves of the heart. They are especially suited

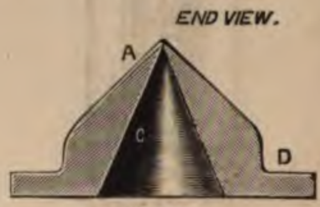


Fig. 789.

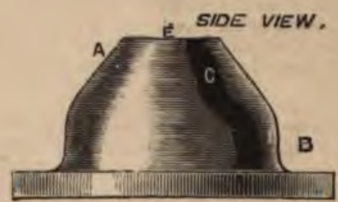


Fig. 790.

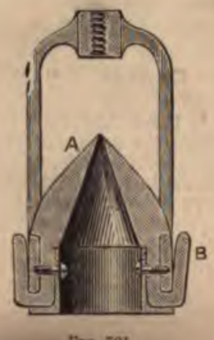


Fig. 791.

for certain work executed in chemical works, and stand very well. Fig. 791 is a section of the bucket to match the rubber valve. Of course, it will be readily seen that the valve may be screwed between the flanges of an iron or other pump, as B shown below.

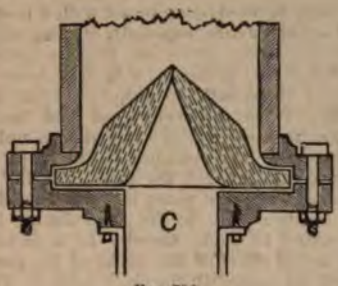


FIG. 792.

FIG. 793.

Fig. 792 illustrates the above valve fixed between the flanges, as at B, C, Fig. 793. Also see Fig. 797.

Chamber, Tail-Pipe, and Relief and Retaining Valves.

The tail-pipe valves, as illustrated at A, B, C, and E, Fig. 794, are valves for fixing on the suction pipe; in fact, they answer the same purpose as the sucker valve, and are nothing more nor less than substitutes for the sucker valve or box. The old school of plumbers were very fond of using these valves upon their pump suction pipes, especially in places where there was a long length of horizontal pipe, say 30ft. to 50ft., buried in the ground, etc. In such places it is quite as well to use one. The place for fixing is about 6ft. down the well, but where such valves are fixed the pump will work a little harder or heavier on account of the weight of the valve, and the extra friction of the water through the additional valve. The reason why these valves are used on the suction is prevent the top or sucker valve receiving the heavy slam k which takes place in long lengths of pipes when dle of the pump is worked and stopped too quickly from the hand stroke on to the back stroke, or, in other words, from the down stroke to the up stroke. It is certain that when water is supported by the atmosphere, or what is generally known as being held up by the clack, that a partial vacuum is easily created in short lengths, viz., if the water is arrested suddenly. Take notice—the strokes in pumping are known to pump-makers and fixers as "hand" or "back" stroke, and also as "forward" or "back" stroke, or as "in" or "out" stroke, whether the rods are working in a horizontal, oblique, or vertical position. Some plumbers will say "up stroke" or "down stroke"; this will answer when the rods do not receive a rocking motion, or when fixed in a horizontal position for reciprocating motion; but the regular pump-hand is known to say "hand" or "back" stroke. These terms are also used in shafting having a rotary motion.

These tail-valves are often fixed upon the rising mains to relieve the valve on the outlet of the barrel, or to keep the constant weight of the water off the stuffing-box and long lengths of pipes. They are then known by the name of retaining valves. A, Fig. 794, is the ordinary tail-

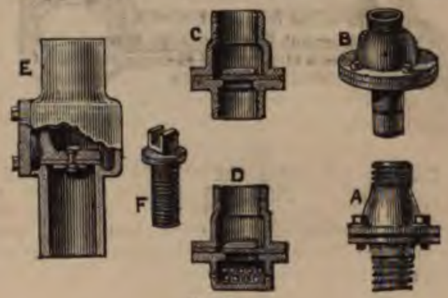


FIG. 794.

valve; B is the retaining valve; C is a section; D is known as the foot-valve; E is a retaining or tail-valve, having the plate for taking out the valve K for repairs, &c. This arrangement often saves a lot of trouble and heavy work in pulling the pipes apart when the valves require to be leathered, &c.

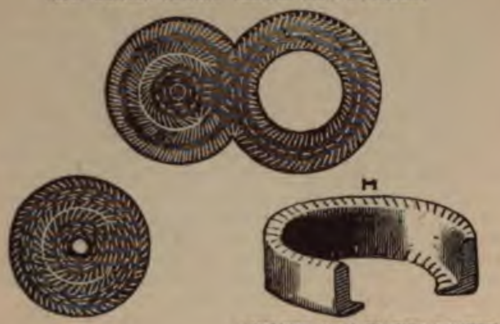
Flange Leathers and Valves.

These leathers are illustrated at Figs. 795 and 796, the latter of which is canvas, for hot water, &c., specially made and sold by brass finishers, pump-makers, &c. By referring

FIG. 795.

to Fig. 800, at A, will be seen a flange; the leather between this flange forms the "sucker valve" B, for a plan of which see A, Fig. 795. When marking these leathers

HOT WATER CANVAS VALVES AND BUCKETS.



QUILTED HOT WATER BUCKET.

FIG. 796.

mark the valve or flat part as follows:—With the compasses strike the circle H I J K, and with the compasses as they are set, divide the circle into six equal parts, two of which are required for the hinge A; next cut the hole B. When cutting out these leathers care should be taken to cut the open part C nice and clean, or true. Of course, you remember that when describing sucker boxes I explained how to treat the leather, by rubbing off all the fleshy part. For making cup leathers, see pump cup leather making.

Earthenware Pumps and Feather Guide Sucker Valves.

In chemical works and earthenware pumps it is a common thing to use "sucker" and other valves having feathered guides, such as illustrated at Q, K, Fig. 797; P is a plan

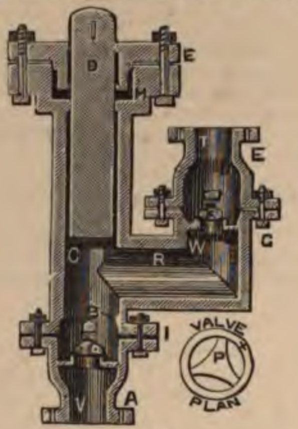


FIG. 797.

of the valve. The feather P must, of course, extend across the valve passage, and by so doing it blocks up the best part of the same, often to the great hindrance of the fluid to be pumped. Badly constructed water valves are often made with their valves this shape. The working parts of this pump will be explained further on. Of course, in the earthenware pump, this shaped valve cannot be well avoided.

Pump Buckets and Handles. (See Fig. 784.)

Of these there are various kinds. The simplest, and the one generally used about London, is that shown at L O P K, *Fig. 784. O is the* rabbet for the fixing of the leather, which should be cut back about $\frac{3}{16}$in. to a $\frac{1}{4}$in., with a ledge as at O, Fig. 784. The rabbet in the bucket engraving, Fig. 784, is cut rather too much back at the bottom; it should be more like that shown at B, Fig. 809. K is the seating for the clack, a plan of which is shown at N, Fig. 781. A, B, C, D, &c., Fig. 784, is the handle and bucket-rod, suitable for the above bucket, and generally made with a leverage of 5 or 6 to 1; see Fig. 781, also my pump gearing and tables. The method of fixing the bucket upon the rod is as follows:—At P, Fig. 784, will be seen a hole bored through the solid wood. Take the bucket-rod and measure upon the solid part of the bucket from P to K the exact distance from the shoulder at E, and the eye of bucket-rod for the key F, to wedge the bucket firmly upon the bucket-rod. Next make the end of the bucket-rod red hot, and push the same through the hole in the bucket, and withdrawing it as quickly as possible, so as not to burn the hole too large; then let the rod cool, after which fix the bucket firmly upon the rod. This is done by first placing an iron washer under the key, then with a wedge-shaped flat split pump-key, such as shown at D, Fig. 787,

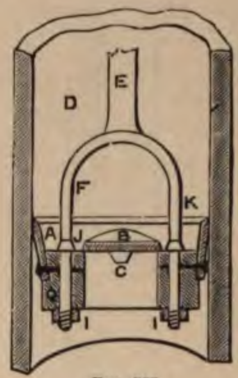


FIG. 798.

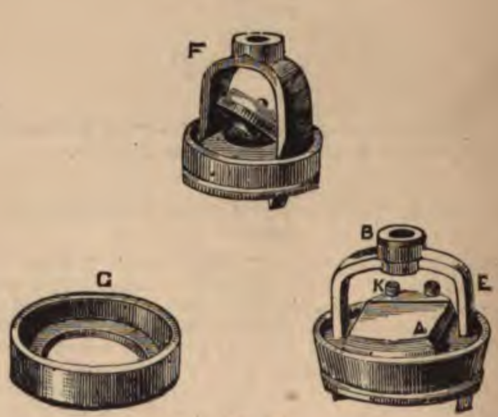


FIG. 799.

driven into the eye, as shown at F, Fig. 784 (also see the rod and bucket as illustrated complete at Q, S, T, Fig. 805), wedge the pump-bucket firmly upon the pump-rod, after which turn the ends of the key round in such a manner that it cannot work out, nor scratch the inside of the pump barrel. Also see that the *head* of the split [illegible] in far enough, so as not to scratch the barr

Leathering Buckets.

Nail the clack on first.

When leathering wooden buckets for pumps, the leather should be of the best sole leather and cut about $1\frac{1}{4}$in. to $1\frac{1}{2}$in. wide, and long enough to go round the bucket and lap from $\frac{1}{2}$in. to $\frac{3}{4}$in. The bottom outside edge should be pared off the outer side of the leather for about $\frac{1}{2}$in. up for the nailing, this allows the nails to stand back as shown at Fig. 798: the ends of the leather should also be pared down so that they will fold over each other without being clumsy, as at W, Fig. 805. When nailing the leather on see that it fits properly; first, it should, when stretched out, appear a little on the curve, to allow for the taper of the bucket. The fleshy side of the leather must be outside. Begin to nail on by first driving a nail about the middle of the leather and every $\frac{1}{2}$in. or so until it is nailed on, as at Q, Fig. 805. It will be as well if you bore through the leather, and about $\frac{3}{8}$in. into the wood, with a fine, round-pointed bradawl, before putting your *copper* nails in, the length of which will vary according to the size of the bucket; a 3in. bucket will require $\frac{3}{4}$in. nails, and a 3in. barrel will take only a $2\frac{1}{2}$in. sized bucket in *measurements*. Sometimes the bucket leather will be too small, if so, cut the leather a little on the splay to cause it to open a little. When under pressure the cut must be done so as to allow the leather to open and yet fit the sides of the barrel. Cut it as shown in the plan at W, Fig. 804.

Short Buckets.

These are much used in the West of England and in many provincial towns and villages throughout the country. For this kind of bucket see P, Fig. 784, also Fig. 798. Q, I, is the wood bucket, whereon the leather A is nailed; E the pump-rod. The bucket is attached to the pump-rod by means of the two forks F J K, known as the languet; and is fastened with rivets, screws, or other equivalents as at I. This kind of bucket is generally used in wood pumps—in fact, I have never put the long wood bucket, as shown at L P, Fig. 784, into wooden pumps. We generally take the old one out, and send it to the wood turners to have one made to pattern, because there are so many different sizes in the bore of these pumps, owing to wear and tear. Next, we have the brass or gun-metal pump bucket, as illustrated at E and F, Fig. 799. These buckets screw on to the end of the pump-rod at B and F, see G, Fig. 800; such pump-rods are, as a rule, made of copper. They work through a stuffing-box, as shown at M, Fig. 800, the one end being screwed into the pump bucket at G, whilst the other is connected with the lever at Y. G, Fig. 799, is the cup leather, and H, Fig. 796, is a quilted cup bucket, suitable for hot water.

Hydraulics, or Atmospheric Jack, or "Suction Pump": Action of. Also Air Chambers.

Let us now examine the theory of pumps generally.

Writers up to the present time have asserted that all pumps are both pneumatic and hydraulic; but when they say that *all* pumps are so, the assertion is not correct, which can be proved by the examination of Fig. 850, or in fact, any pump whose barrel is submerged above the bucket line. At the same time, I entirely concur with those who have written "whoever understands the one, will be at no loss to understand the other." Without some knowledge of the science of pneumatics, it is next to impossible to [illegible]tand hydraulics. It will be necessary for me to [illegible]ufficient of pneumatics to enable you to understand the principle of the "suction-pump." I use the word *suction* because it is universally understood by plumbers, and it is common amongst them to call a jack-pump a "suction-pump," and *vice versâ*. In fact, it is very rarely that you meet with a pump without a suction-pipe in some shape or form. All jack and plunge-pumps, also most of the lift-pumps, have a "suction-pipe." The term, "suction," in relation to all pumps, is generally accepted and commonly used by plumbers; hence the reason why I use it.

Experimental Pump.

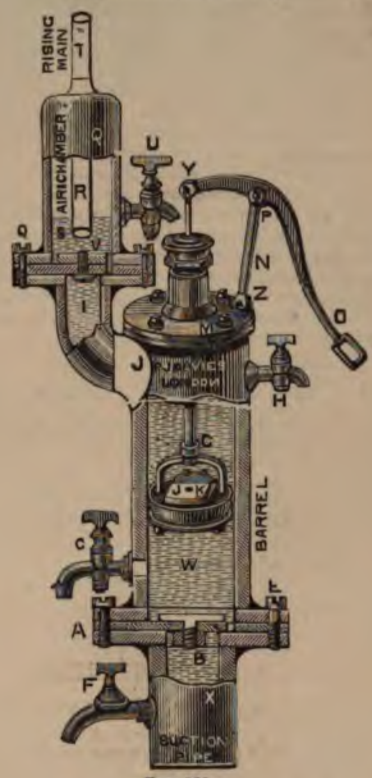


FIG. 800.

X, Fig. 800, is the suction-pipe leading to the source of water supply. B is the sucker-valve, opening upwards, so called because the weight of the water from below always tends, as it were, to suck this valve through its seating, or it may be the water above tending to force it upon its seating. W is the working barrel, so called because this is the chamber wherein the bucket G is made to work. I is the outlet water way, leading either to a cock or spout, and after into a cistern, or otherwise. Upon the upper part of this water way, at V, is a valve-seating, of course, opening upwards. One of the tail valves, A, B, E, or C, Fig. 794, will answer here; but as you progress you may find that, for the *real* action of this pump, the valve is not required, as is the case with that shown in Fig. 846; but note the difference in Fig. 840, the rising main valve must be used simply because there is no valve in the bucket, or, as is the case here, plunger. Q, Fig. 800, is an air chamber, which should be at least ten times the capacity of the working barrel, or of the water lifted at each stroke. But for my part I go further, and

make the size of the air chamber in proportion to the height of the column of water lifted, as the higher it is lifted the more will the air within be compressed, as follows:—

Air Chambers Explained.

Suppose the air-chamber to be full of air. Now, suppose it to be pumped half-full of water: it follows that the air has been compressed to one-half of its original bulk; and, therefore, its spring is twice as great as at first, and will resist a column of water in proportion. Here the pressure of the air in the water, and internal parts of the air chamber, will be, say, 15lb. on the square inch, and will be equal (as we say that a 30ft. column of water will equal 15lb. per square inch) to the pressure at the bottom of a column of water 30ft. in height. For our work this in practice will be quite near enough, but for more accurate work see headings, "Atmospheric Pressure and Specific Gravity of Water," also see "Pressure of Water per Square Inch"; "Hydrostatical Paradox," &c. Now, suppose the air to be compressed to two-thirds of its original bulk, its spring will be three times as powerful as it was at first, and will force the water twice 15lb., or 30lb., to the square inch, or up a pipe 60ft., known as two atmospheres. Compress the air to one-fourth, then the water will rise three atmospheres, or 90ft., and so on, according to the following table:—

Height of water in pipe.	Spring on the elasticity of air.	Air compressed in bulk.	Number of atmospheres.	Height of water in chamber.
30	2	$=\frac{1}{2}$	1	$\frac{1}{2}$
60	3	$=\frac{1}{3}$	2	$\frac{2}{3}$
90	4	$=\frac{1}{4}$	3	$\frac{3}{4}$
120	5	$=\frac{1}{5}$	4	$\frac{4}{5}$
150	6	$=\frac{1}{6}$	5	$\frac{5}{6}$
180	7	$=\frac{1}{7}$	6	$\frac{6}{7}$
210	8	$=\frac{1}{8}$	7	$\frac{7}{8}$
240	9	$=\frac{1}{9}$	8	$\frac{8}{9}$
270	10	$=\frac{1}{10}$	9	$\frac{9}{10}$

If you examine the last figures in the table, you will see that the air is compressed into a very small space. Now, the useful effect of the air in the chamber is reduced to a minimum, nine-tenths of its capacity being filled with water. Now, to make the air chamber work with proper effect, more air is required within it—which air, in reality, forms a cushion, whose elasticity prevents the sudden strains, jerks, or blows (known as the rattling) upon the bucket, valves, and sides of the pipes or pump. The following method is the one I some twenty-five years ago adopted, and I believe that I was the first to do so. Having the water within the rising main, and the pump properly charged, open the cock C, Fig. 800, and pump air into the air chamber; or from a stop-cock, say, at U, Fig. 800, or at A, Fig. 801, pump the air-chamber full of air: when the chamber is full, the air will bubble through the rising main, and if you do not look out it will blow all the water out of the rising main, therefore pump slowly and leave off when you think you have enough. The pump will now not only work with a more continuous flow, but if worked by hand and lever, it will work easier. Of course, simply because the cushion of air is increased (though under the pressure of the column of water within the pipes) to its original size. See "Expansion of Air and Gas by Heat."

Concussion in Pipes (Prevented).

In long suction or rising mains, especially with single barrel pumps, owing to the continual stoppages and re-starting water column, the concussion is very noticeable, and may always be stopped by the use of the air chamber.

Fig. 801.

These air chambers are nothing more or less than closed vessels, often having the end of the rising main terminating near the bottom, as at S, Fig. 800; or, in other words, having no outlet whatever, more than one-third of the diameter of the rising main above its bottom. Suppose the rising main, R, to be 3in., then its end may be brought to within 1in. of the bottom. *But in pumps like that at Fig.* 800 *take care that this pipe does not come against the top of the valve when the valve is up*, otherwise the pump will work exceedingly hard, on account of the great friction of the water when passing through a partially closed aperture. N, Fig. 800, is the rocking standard, which allows the handle to be lifted, and which, if not movable upon the joint Z and P, would prevent the handle being worked. This is a cheap kind of pump-gearing, but not so good as the ordinary lift pump gear, shown at Figs. 842, 858, &c. Now, suppose the barrel W, Fig. 800, to be full of water, as shown by the water lines, and the bottom valve B to be holding it up, the bucket fits the sides of the barrel quite truly, and notice this, that the greater the pressure upon the bucket the tighter will it fit the sides of the barrel, simply because the bucket has an outside casing of stout leather, which expands laterally with the pressure from above. The outer edges of this leather are slightly bevelled, as shown at A, Fig. 798. In the centre of the bucket, Fig. 800, is the flap-valve K, which opens upwards, and allows the bucket to descend freely. On pulling the bucket up, the flap-valve J K instantly closes, and the cup leather expands, because the weight of the column of water above the bucket has been lifted off that below; and if the valve B was perfectly closed, or a stop-cock wiped on the suction-pipe, and closed, there would then be a perfect parting of the water below and the bucket. Suppose there to be one inch of water below the bucket and the top of the valve B, and that the bucket be lifted 9in., then there would be an empty space of the 9in. This is a truly empty space, void of all matter or air, and is called a vacuum. Now, let go the handle of the pump: the bucket will then go back, but will the vacuum still be in the barrel of the pump? The answer is, Yes! It will now show itself at I, below the outlet valve; and the water that was at the point I, will, by gravitation, fall back upon the bucket. Open the cock H, and what will be the effect? Air will rush into the barrel to fill up the empty space or vacuum. But, suppose, instead of opening the cock H, the c
had been opened below the bucket, would the air th
rushed in and opened the flap-valve K? Yes! N
off the cocks, and again fill the barrel as before, o

keeping the "suction-pipe" (which does not exceed 27ft.—5 or 6ft. would suit better) closed. Now pull up the bucket, and another vacuum is produced. The top valve V will prevent the water or air returning, and you may now work the bucket freely up and down the barrel. You know that when the cock H was opened that the air rushed into the barrel. Now, place the end of the "suction-pipe," say, 2 or 3ft. long, into water, and open the supposed stop-cock on the suction-pipe. The consequence will be that water will rush up the suction-pipe instead of air. But why? Simply because the end of the suction is covered with water, and no air can get into the pipe by reason that the water is there and the air or atmosphere is not strong enough or of sufficient weight to get through the water. (Should the pipe be too large for the water to show itself in the barrel, perhaps a few strokes of the handle will "fetch" it; or, for the purpose of illustrating this action, a small compo. pipe may be used, whose length is in proportion to the size of the barrel.) Now the barrel is full of water, as also the suction-pipe, open the cock F, and air will rush in, and allow the standing water within the suction-pipe to descend. But why? Simply because the air is allowed to press with the same force on the surface of the highest point of the water inside the "suction-pipe" as on the outside. Turn the cock F off again, and lengthen the suction-pipe to 34ft., and let the water be "*drawn*" (which is an ordinary plumber's phrase) vertically this distance. Pump away as before. No water can be obtained. But why? You have the vacuum as before, when the "suction-pipe" stop-cock was turned off, and the water is standing in the suction-pipe, and within 1ft. or so of the barrel or valve B. This is what is known as the pump being out of draught. To prove this, shut off the before-mentioned imaginary "suction"-pipe stop-cock, whose distance from the valve B is, say, 5ft.; let F be fixed 3ft. from the valve B: open the cock F, and you will find a slight rush of air enter the cock, after which the column of water runs out; but not with the kind of cock shown at F, because this cock answers the purpose of a cistern to a barometer, and prevents the air entering only to the degree of one common atmosphere. An ordinary ground-in bib-cock, as at C, will admit the air. (Notice.—It often happens that you, a plumber, have to turn off the water from a cistern whose pipes are fixed vertically, and so arranged that they should drain themselves empty). You turn off the stop-cock near the cistern, and open the bib-cock below, which, if of the screw-down kind, such as the Rotheram, Brighton, or the diaphragm pattern as at F, the water will be, by the atmospheric pressure, held up to the height of 30 to 33ft. above the cock; but should there be a common ground-in cock on a higher level, then the highest cock, if opened, will allow air to enter the pipe, and the water imprisoned within the pipe to fall to the cock below. You have seen that the water will only rise up the suction-pipe to the height of 30 or 33ft. Why is this? I must say that it would not rise 1in. were it not forced up. You know that when you had a vacuum in the barrel the air rushed into it on opening the cocks H and C. Then there was a proof that there must be pressure upon the outer side of the pump barrel. This pressure is at all times pressing upon every part of the world's surface to the extent of about 15lb. to the square inch, more or less. This atmospheric pressure was fairly explained at Fig. 285, "The Principle of Siphonage in Traps," and should be thoroughly mastered.

Expansion of Air or Gas by Heat.

-ve are on the subject of air it will be as well to -xpands or contracts like most other substances,

Convert Fahr. deg. into Cent. deg.; then, as gases expand $\frac{1}{273}$rd part of their volume at 0° C. for every increase of 1° C., it is evident that 273 volumes of a gas measured at 0° C, when heated to

1° C. will become 274 vol. = $(273 + \frac{1}{273}$ of $273)$
2° C. ,, 275 ,, = $(273 + \frac{2}{273}$ of $273)$
30° C. ,, 303 ,, = $(273 + \frac{30}{273}$ of $273)$

With regard to the pressure, the volume of a gas is inversely as the pressure which it sustains, if the temperature remain the same. Thus, suppose 100 vols. of a gas are measured off at the standard temp. and pressure (0° C. and 760mm. bar.) and it is required to find the volume occupied by the gas when the pressure is reduced to 730mm., the temp. remaining the same. The volume will be inversely proportional to the pressure: $730 : 760 :: 100 : x = 104{\cdot}1$ vols. at 730mm. (2) There is no general law respecting the expansion of liquids, as all liquids expand differently.

"Suction" Pipes (Length of).

I told you that by reason of the vacuum 30 or 33ft. of water had risen in the "suction"-pipe. Now, settle that it was 30ft., and that every foot in height is equal to ½lb. in weight on a square inch; it follows, therefore, that 30ft. will equal 15lb.; this, the atmospheric pressure, is, with the 30ft. column, truly balanced, and the consequence is that no higher can the water be forced up within the "suction"-pipe of a pump by simple external or atmospheric pressure. It should be borne in mind that the further the pump is fixed vertically from the surface of the water, the more sluggishly will the air press the water up the "suction"-pipe; consequently it is best to fix the barrel within 15 or 18ft. of the water. I rarely exceed 10ft. I had better here remark that horizontal distances are not taken into consideration with atmospheric pressures, or with the action of the atmospheric pump, or with vertical height of the "suction"-pipe of a pump, as this kind of pump may be made to draw miles horizontally, provided the barrel does not, in height, exceed the limited distance of 30ft. But it would be by far better to lift the water to this height and then let it find its level by gravitation, as the starting and stopping of the column of water in long lengths of horizontal piping requires much force to put it into action, viz., suddenly.

The Lift Pump (Action of.)

We now know the action of the atmospheric pump; let us proceed to examine the action of the lift pump. For this purpose let us again refer to Fig. 800. Suppose the barrel to be quite full of water up to the valve V; let this valve be fixed down on its seating, or, say, perfectly closed; push up the handle O, this will cause the bucket to descend and the valve J K to open. Now, pull the handle down, and the valve J K closes, and you will find the whole thing will not move. It is as rigid as a post. Why? Simply because the cup leather fits truly, the bucket valve tight, and that there is no outlet above. It is no use trying to compress water; in fact, you may say that with this kind of tool it is one of the impossibilities to compress water. Some idea of this may be gathered when I inform my readers that under the common atmospheric pressure of 15lb. to the square inch, water has been diminished in bulk only to about 45 parts in one million, and that under the enormous pressure of 15,000lbs. to the square inch, it was only compressed by about $\frac{1}{24}$ of its volume. This experiment was tried in a bronze solid cast and bored 3in. tube, 8in. thick, and was rent in halves by this enormous pressure, yet with all this, water is exceedingly elastic when not confined.

This being the case that we cannot very easily compress water, we must provide an outlet before we can work the handle of the pump, Fig. 800. Open the valve V and the cock U; the pump being worked, the water will flow up, and out of the cock U, which now close, also close the rising main T with a stop-cock, the water will now rise in the air chamber according as it is compressed within the chamber, and as shewn in the table.

Of course, by continuing the action of pumping, great pressure will be accumulated in the air chamber, and, in fact, it will burst if proceeded with. But now open the stop-cock on the rising main, and the pressure of the air on the surface of the water will cause the water to ascend in precisely the same way as the air does when pressing upon the surface of the water in a well, and when the air is relieved or exhausted in the suction-pipe of a pump.

You have seen one of the important uses of the air chamber. There is another great reason for its use. It is most essential in all fire-engines: without it we should not get that regularity in the jet, in fact, the jet would be a continuation of jumps; but, by the use of the air chamber, there is a constant pressure maintained, and this gives the desired effect of a continuous stream. It is at times used on "suction"-pipes, see Fig. 802, and as near the barrel of the pump as convenient.

FIG. 802.

Fig. 801 illustrates different air chambers, which are generally made of copper. A B C is a section, D an elevation, F G is an elevation of one generally used for fire-engines on board ship. A is the inlet, B a pipe coming to within a few inches of the bottom, C the outlet. But, as a matter of course, it is not necessary that the pipe B should pass through the top of the chamber, but may come off as at A, or as at M, Fig. 829; nor is it at all necessary that the outlet should be in connection with the air chamber. For a further explanation of the air chamber, see "suction"-pipes and mains, Fig. 802, also Fig. 811, &c. My having shown and illustrated the theoretical and practical working of the pump, you will now be in a position to follow me, step by step, through the remaining portion of pump-work, which will require your particular study, inasmuch as it is my intention to explain thoroughly all the principal parts of the different pumps used for the various classes of work which I have met with during the last thirty-five years; after which, you will be able to select pumps and fittings suitable for any class of work which may be required—a great desideratum to the plumber.

Tree and Lead Pumps.

Sometimes it happens that the tree pump is only used in places where it is exposed to very rough, frosty weather, or where the lead pump is likely to get stolen. In this case, the top-tree or barrel of the pump is made as usual, and let down into the earth, say, 3 or 4ft., to keep it steady. Then a leaden pipe is flanged to the side or otherwise, and taken a short way in a horizontal direction, and through the crown of the well and down to the water (or in some cases, the lead pipe is only used for the horizontal part of the work); but take care to have the pipe laid with a good fall towards the well, so that it will empty itself when required. If otherwise left, the confined air lying within the pipes forms a trap sometimes known as a pocket, which will be difficult to remove. Such a pocket may be seen at F or E, Fig. 803. In such cases fix a retaining or tail-valve on the "suction"-pipe in the well, as shown at tail valve, Fig. 803. When tree and lead pump work have to be done, take care to make the flange large enough for nailing, so that it may be perfectly air-tight to the tree, if the horizontal distance or depth be great, a considerable concussion, when the pump is quickly worked, will take place; then use a suction or vacuum air-chamber fixed as shown at Fig. 802, and as near as possible to the tree or barrel of the pump, see Figs. 811, 812 and 813.

Air Pockets or Traps in Suction Pipes.

When fixing a suction or Jack pump having long lengths of horizontal pipe, great care should be taken to fix it in such a manner that it will fall towards the well, and without air pockets or traps, as illustrated at Fig. 803, and

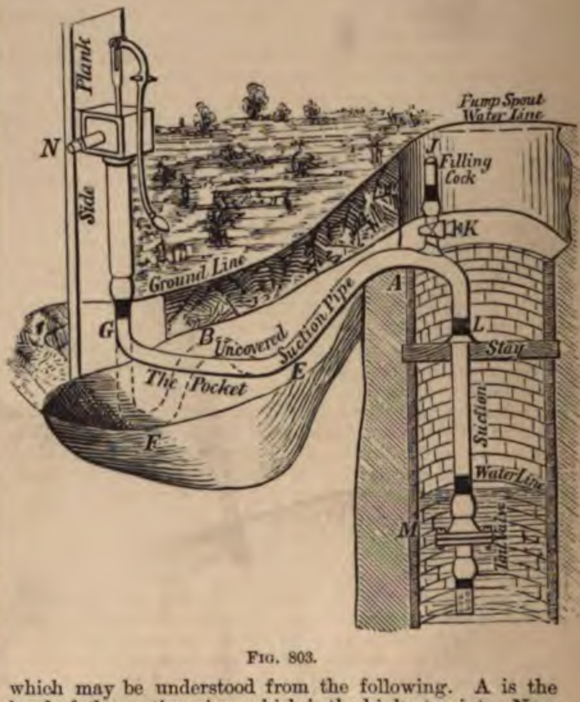


FIG. 803.

which may be understood from the following. A is the bend of the suction pipe, which is the highest point. Now follow this line of pipe to E G. It is clear that when you first work the pump to get water, that you must put water into the barrel of the pump, and then the air between the water in the barrel and the water within the well is confined. You work away at the pump handle, and pump sufficient air to allow the water from the well to rise t bend at A, when it pops over in a small dribbling and runs down the suction to E G; at the same tim

suction pipe not being filled with the running water) the air from E bolts back to A, and every time the handle is worked, this air runs from A to E, and again breaks through the water (again passing to A), as the water spreads itself out in the line of pipe between A and E.

In some cases you can get over this by reducing the size of the suction pipe between G and A so as to cause the water to flow very rapidly through the pipes so as not to allow the air to return. Or at others, you can manage this by taking very quick strokes, and like so many very sudden snatches of the handle, especially the up-stroke, get the suction pipe once filled up. But if you cannot manage to do this, then fix a foot valve as at M below the water level, and fix a short length of pipe and stopcock as at J, and fill the suction until the water runs out at the nozzle—the pump will then work properly; but be sure to have a good foot valve, and a thoroughly good cock at K; or, what is cheaper, and I think, perhaps better, wipe on a 1in. cock-boss or ferrule, and screw in a good iron plug with red lead; but be sure that the pipe J is perfectly full of water when the stopcock is turned off, or the plug screwed in. This is of the greatest importance.

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Lead "Jack"-Pump.

In many country shops, plumbers have to make up their own lead pumps from a straight length of pump barrel as follows:—take a length of, say, 3in. or 4in. pump barrel,

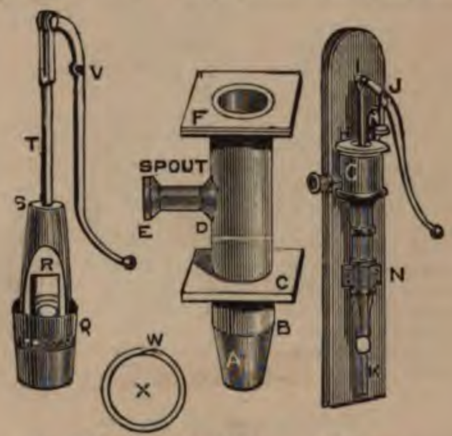


FIG. 805. FIG. 804. FIG. 806.

then saw off about 2ft. 6in., and with a dresser beat the cone-shaped sucker-box end to the shape shown at A, Fig. 804. The cone is generally made from the shoulder to the

A FIG. 809. B

FIG. 807.

FIG. 808.

This being the case that we cannot very easily compress water, we must provide an outlet before we can work the handle of the pump, Fig. 800. Open the valve V and the cock U; the pump being worked, the water will flow up, and out of the cock U, which now close, also close the rising main T with a stop-cock, the water will now rise in the air chamber according as it is compressed within the chamber, and as shown in the table.

Of course, by continuing the action of pumping, great pressure will be accumulated in the air chamber, and, in fact, it will burst if proceeded with. But now open the stop-cock on the rising main, and the pressure of the air on the surface of the water will cause the water to ascend in precisely the same way as the air does when pressing upon the surface of the water in a well, and when the air is relieved or exhausted in the suction-pipe of a pump.

You have seen one of the important uses of the air chamber. There is another great reason for its use. It is most essential in all fire-engines: without it we should not get that regularity in the jet, in fact, the jet would be a continuation of jumps; but, by the use of the air chamber, there is a constant pressure maintained, and this gives the desired effect of a continuous stream. It is at times used on "suction"-pipes, see Fig. 802, and as near the barrel of the pump as convenient.

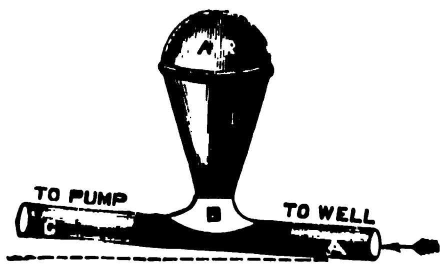


FIG. 802.

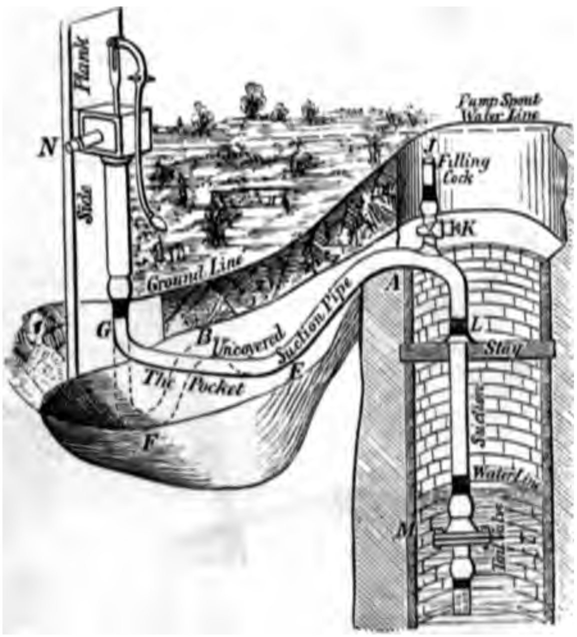
Fig. 801 illustrates different air chambers, which are generally made of copper. A B C is a section, D an elevation, F G is an elevation of one generally used for fire-engines on board ship. A is the inlet, B a pipe coming to within a few inches of the bottom, C the outlet. But, as a matter of course, it is not necessary that the pipe B should pass through the top of the chamber, but may come off as at A, or as at M, Fig. 829; nor is it at all necessary that the outlet should be in connection with the air chamber. For a further explanation of the air chamber, see "suction"-pipes and mains, Fig. 802, also Fig. 811, &c. My having shown and illustrated the theoretical and practical working of the pump, you will now be in a position to follow me, step by step, through the remaining portion of pump-work, which will require your particular study, inasmuch as it is my intention to explain thoroughly all the principal parts of the different pumps used for the various classes of work which I have met with during the last thirty-five years; after which, you will be able to select pumps and fittings suitable for any class of work which may be required—a great desideratum to the plumber.

Tree and Lead Pumps.

Sometimes it happens that the tree pump is only used in places where it is exposed to very rough, frosty weather, or where the lead pump is likely to get stolen. In this case, the top-tree or barrel of the pump is made as usual, and ...ay, 3 or 4ft., to keep it steady. Then a leaden pipe is flanged to the side or otherwise, and taken a short way in a horizontal direction, and through the crown of the well and down to the water (or in some cases, the lead pipe is only used for the horizontal part of the work); but take care to have the pipe laid with a good fall towards the well, so that it will empty itself when required. If otherwise left, the confined air lying within the pipes forms a trap sometimes known as a pocket, which will be difficult to remove. Such a pocket may be seen at F or E, Fig. 803. In such cases fix a retaining or tail-valve on the "suction"-pipe in the well, as shown at tail valve, Fig. 803. When tree and lead pump work have to be done, take care to make the flange large enough for nailing, so that it may be perfectly air-tight to the tree, if the horizontal distance or depth be great, a considerable concussion, when the pump is quickly worked, will take place; then use a suction or vacuum air-chamber fixed as shown at Fig. 802, and as near as possible to the tree or barrel of the pump, see Figs. 811, 812 and 813.

Air Pockets or Traps in Suction Pipes.

When fixing a suction or Jack pump having long lengths of horizontal pipe, great care should be taken to fix it in such a manner that it will fall towards the well, and without air pockets or traps, as illustrated at Fig. 803, and



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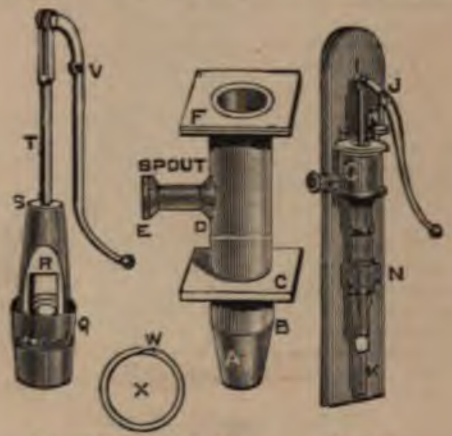

FIG. 805. FIG. 804. FIG. 806.

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A FIG. 809. B

FIG. 807.

FIG. 808.

end 4in. to 5in. long; but for this see size of "suction pipes" further on, as this will have something to do with the length of the cone, so that you may make it nearer to the angle of repose. Next prepare the nozzle; this is made as follows:—Take a piece of 1½in. or 2in. pipe according to the size of the "suction-pipe" (or better still, if one size larger pipe be used), and wipe it into the barrel as shown at D, and at about 9in. from the top. The flange E is wiped on, or a bend turned over, as you choose; next wipe on the fixing flanges C and F, Fig. 804, and the lead work is completed. Next is the fixing; but before proceeding with this, let us see what other kind of jack-pumps are to be made. For this refer to Fig. 806, which is a hand-made "jack" mounted on a plank with tacks as at M, and will be readily understood as we proceed with the work. Fig. 810 is the kind of pump used about the suburbs of London. It has a cast-barrel, nozzle, and a compensating or regulating head as shown at L, and which causes the flow of water to be more continuous than when the nozzle is branched direct into the barrel, as shown at D, Fig. 804.

London-made Lead "Jack" Pumps.

In London, and for about twenty miles around, lead pumps are made similar to that shown at Fig 807, viz., barrel, head, and nozzle, cast separately and burnt or soldered up. The former, if done by a tradesman, being much the best; but I have moulds for casting the lot in one piece.

At Fig. 808 may be seen the necessary iron work for such pumps, and Fig. 809 at A and B, the wood bucket and sucker box which is usually sent out when ordering these pumps from the lead merchants. But to make sure of having the lot complete it is best to order lead pumps with iron work bucket and sucker box, either leathered or not leathered.

Making up Lead Pumps.

In Fig. 810, M is the nozzle, and N the barrel; these parts are cast in iron or gun-metal and other shut-up moulds with slightly taper cores, then soldered up as follows:—Soil the inside of the front L of the compensating head. Next cut the hole where required for the nozzle, leaving an inch or so of room for the water to stand in the head, and fit the nozzle in up to the shoulder V; then take it out and shave the inside part of the hole within the head, 1¼in. all round; after which, soil the inside part of the nozzle, and stuff a clean cut wad of paper into the end V (but with its end quite level with the hole) of the nozzle, and shave round the outside down to the shoulder, after which fix it and solder it into the head by making a flange joint. Next fit the barrel into the head, soil and shave it, say, from 1¼in. to 1½in. all round; next soil the outside part of the barrel shoulder at X, and, by placing the head upside down, you can readily solder the barrel on to it, when the pump is ready for fixing, or for the suction to be soldered on. *Notice*, the top of the barrel should protrude through the bottom of the head, say 1in.; this prevents bits of brick, gravel, &c., from so readily falling down the barrel. This gave rise to the introduction of the head to lead jack pumps, first done by my old friend, Mr. Longrove, plumber, about the year 1851. The head is at times made round, and at other times with round front and flat back, so that it can be fixed with ears, as at N, Fig. 804, against a post or plank, as shown at A, Fig. 817. Of course, the plank for support may be fixed in a shoe as at Q R S T, Fig. 890, or as at Z, Fig. 868, or let into the earth; or it may be fixed against a wall with a handle working from the back of a plank, as at K, Fig. 817. The fixing of these pumps, when exposed, is subject to three evils—namely, the frost of winter, theft, and the possibility of children putting things into the barrel; but when fixed as

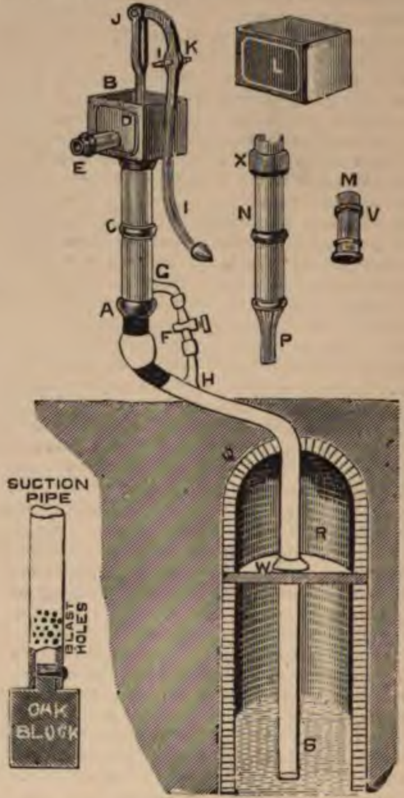


FIG. 810.

at Fig. 817, it can be packed with wool, felt, &c., and is protected from theft. A bent nozzle prevents the children putting stones into the barrel. Sometimes iron cases over the lead, or brass spouts are used to prevent theft of nozzles.

"Suction" and Rising Main Pipes (Size of.)

It is important that the "suction" and rising main pipe should be of a sufficient diameter to allow the water to pass without undue friction; for instance, suppose the barrel C, Fig. 810, to be 4in. diameter, and the suction-pipe R to be 1in., by working the handle it will be plain that the water when passing through the 1in. suction pipe will travel 16 times faster than through the 4in., and at the expense of needless labour, which is solely caused by friction, momenta, &c. This is apt to be overlooked by most *modern* plumbers, but it is of more importance than is generally supposed, especially in long lengths of pipe. In practice it may be observed that the pumps which work lightest on the hand are the tree pumps. Why? Simply because their bore is of a larger diameter, and as a rule the bucket is not too far from the surface of the water within the well.

As before said nearly all suction-pipes and rising mains should be at least one half the diameter, or one-fourth the area of the barrel; that is to say, a 3in. barrel should have a one and a half inch suction pipe, and if of a very long

length, this suction pipe should be larger, or 2in. to counterbalance the effect of starting and stopping of the water, which is plain, if you consider that the water will move slower in a large pipe than in a small one. The same rule holds good for double-acting pumps, as each barrel forces or draws the water at different intervals, or, in other words, alternately.

I have referred to, and explained the use, size, and action of, the air-chamber, and only have to say that whenever a sudden jerk is felt upon the lever, or a chattering or thumping noise is to be heard within the pipes of a pump, whether it be on the suction or rising main, an air-chamber is required, and of sufficient size to prevent this, which is due to the sudden stopping of the advancing column of water at each hand or back-stroke of the pump; this is not so much felt in wheel or frame pumps, the action being regular. Should there be an air-chamber fixed, and then this chattering noise heard, it is pretty certain that it is in the wrong place, or out of order. The air-chamber should be fixed as near to the pump as possible; it may be that the chamber is full of water by reason of the air escaping through a pinhole, &c., in the material or it may be caused by bad brazing, soldering, &c. or perhaps, as I once found one in the well, some 200 ft. deep, at Fairfield House, Hornsey, near London, fixed upside down. This latter pump rising main, although a frame or wheel pump, was a continual nuisance, on account of its bursting. The *London* plumber who fixed the pump had for some months a regular repairing job. I was called in, and at once, on discovering the chattering, concluded that there was no air-chamber; but, to my great surprise, there was! I inquired if it leaked, as an air-chamber if leaky will show the water running down the sides, unless the leak is in the dip-pipe, which is a thousand chances to one that it is not. There was no leakage. I knew something was wrong, and down I went. The air-chamber was of the shape shown at Y, Fig. 801; but the one shown at D, Fig. 801, is the most likely to be found fixed upside down, simply because the top is the largest, and many London plumbers, though excellent roof and closet hands, take it for granted that this is the bottom, and argue the point that the water should run from R to A, on account of the taper, which at first sight seems very reasonable. A simple method of ascertaining whether the air chamber is charged or not is by sounding it, or by pricking a small long hole (on the top), say with the end of a carpenter's sharp chisel, or the point of a pen knife or fine bradawl. This I did, and found the air-chamber to be full of water. The air-chamber was cut out, when, instead of the water running out, it remained full, which at once showed that the air-chamber was fixed "wrong way about." If you turn the air-chamber A B C, Fig. 801, upside down, you will see that the water cannot get away, because the dip pipe holds it up. When you get the cylindrical-shaped air-chamber, as shown at Y Z, Fig. 801, instead of the conical, you can distinguish the top from the bottom, by pouring a little water into it, or by pushing a stick down the one end, when you will feel the end of the dip-pipe. The dip is always the same as the dip of the D-trap.

Air-Chamber "Suction Pumps," also known as "Cistern Pumps."

Fig. 811 is a section of this pump, and Fig 812 is an elevation. J is the vacuum air-chamber and cistern, wherein is fixed the barrel B and bucket. In the air-chamber E I is the tube, wherein works the bucket rod, which also (on top) works through a stuffing box K. The tube I E prevents the air in top air-chamber A from working out at the stuffing box. The action is as follows:— On raising the handle the rocking standard N gives way, and the connecting rod L prevents any lateral strain from being put upon the piston or bucket-rod when the bucket-rod descends, and on the down stroke the bucket ascends and brings with it the water out of the cistern J without any recoil in the suction pipe, no matter how quickly it may be worked, or if the draught be just within the limit of, say, 26ft., the atmospheric pressure quickly, or if in a long draught, slowly presses the water up into the cistern J, and by the time the bucket is down again plenty more water is in the cistern, so that this cistern is a ready means of preventing the suction pipe from kicking or chattering. Of course, the air-chamber A I answers its usual purpose, should the pump nozzle be stopped up and a rising main fixed on at A, or a hose fixed on at M, for garden or other use.

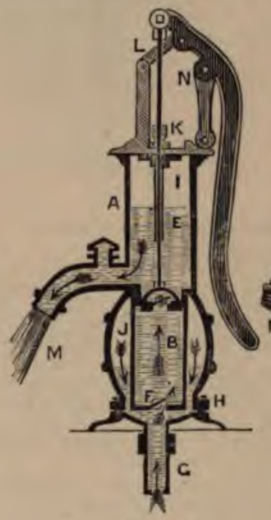


FIG. 811.

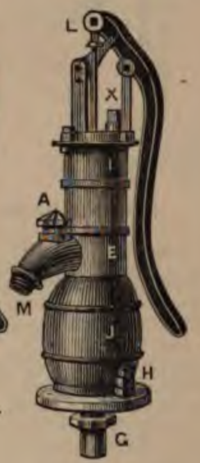


FIG. 812.

Parallel Motion Gear.

In the Figs. 811 and 812 is shown a simple means of producing a parallel or perpendicular stroke suitable for pump rods: L being a fixed standard jointed at L, and which allows the rocking standard N to move without strain being thrown on the piston rod of the pump.

Continuous "Primed" Pumps.

This pump is illustrated at Fig. 813, the bottom of the barrel has a valve, which dips into an outer cylinder, which is supplied with water from near its top edge at the flange on the right. Suppose the pump valve to let by, and the suction and rising main to be empty, as the water falls to the bottom clack so will the air follow, but as soon as it passes through this valve, it will then quickly bubble through the water contained in the outer chamber, and so allow the water in the suction pipe to fall, and as soon as this is all out, the water contained in the outer chamber falls back, and part again goes into the pump barrel for the bucket to dip into, and thus the pump is continuously primed; a better arrangement of these pumps is to be seen at Figs. 838 and 852.

FIG. 813.

Foul Air in Wells, and Air Pumps.

(*Also see Fig.* 867).

Before you enter *any* well be careful to *personally* examine the same for the presence of foul air, trust no one, for you cannot be too careful with your own life; hundreds of men have lost their lives in wells through trusting to others. Remember that wells which have been found to support life, one hour afterwards have been found to destroy it by reason of the presence of carbonic acid gas, and especially remember it is absolutely necessary to test for this foul air at all times when you have occasion to uncover a well.

A man is a fool to rush headlong into his grave by descending into a space filled with carbonic acid, a gas which cannot support life, nor can it be seen, but it will smother the strongest animal in the world. Always lower a lighted tallow candle to the water or nearly so before you descend into any well; if the candle burns, you are safe; *if not, do not, upon any consideration,* venture down until this deadly and treacherous enemy is driven out or cleared away, which is done as follows, viz., by lowering anything to cause heat, so as to rarefy the air, or by blowing air from a blowing-machine; a first rate blower is shown at Fig. 63, and is light to carry about, and can be used with the ordinary $\frac{3}{8}$ in. rubber tubing, or another blower, but five times the expense, and no better, is shown at Fig. 814; or by the use of a gas and hot water, or blacksmith's portable forge, or to blow down a lot of iron, india-rubber, or other pipes, and which must reach down to the water, or nearly. Sometimes the rising mains (not having tail or chamber-valves) are made use of for this pumping down fresh air. This is done by fixing a ball stop-cock upon the main pipe near the barrel, or just above the retaining valve, with a pipe leading to the surface of the water in the well. Such ball-cocks, if we may use the term, are best worked with rods reaching from top to bottom, as shown at A, Fig. 774. Of course, by attaching a rubber hose on the outlet of the main, and by pumping air down the main in large quantities, the foul air will soon mingle with the fresh air and rise to the surface, when the candle will burn.

FIG. 814.

Well Windlass.

Also see Fig. 1222, *and description.* (*Mechanics for Plumbers.*)

It may be asked, "How am I to get down a well?" You should be let down by the aid of a windlass, and wound up upon a rope such as shown at ROPE, Fig. 815.

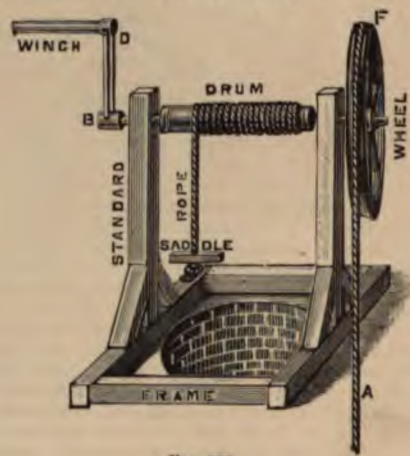


FIG. 815.

Two men take the windlass, one on each side. The other handle is not shown on the wheel, but that does not signify. Sit across the SADDLE with the rope between your legs, and at first, until you are used to the work, with a piece of sash cord over the right shoulder round the rope and under the left armpit, and away you go grandly to the bottom stage. If you have never been let down before, you will have some very peculiar feelings as you descend, and will be full of wonderment as to whether the brickwork is safe? are the stages safe? and will anything fall? Is it a way down! Suppose that the rope should break, or those on the top should accidently let go the winches! Then you wonder if there is any foul air in the well. All this is running through your mind as you first go down. Shall I fall off? Then, if a very deep well, you may see that the brickwork is winding, and the chances are, that you will say to yourself, "This is not a safe well." Perhaps there are a few bricks out in places, or that you may be in a dangerous well; then you will, from the first moment of

your descent, wish yourself on top again. All this will pass through your mind, and this is the very thing, if you are in safe and trusty men's hands, that you must forget, for it only makes you more nervous, and under the influence of such wretched feelings, men have been known to faint and fall off, as though foul air was in the well. A plumber has no right to enter a well if he has an idea that he cannot stand the first horrors of well work, more especially if it be a dangerous well. For example, sometimes you will have to descend 50ft. or 100ft., and then walk along a heading perhaps 60ft. or 100ft., or even 1,000ft. (in this latter case it is wise to sink another shaft, then the heading is only required for the suction pipe to lay in), then go down another well (perhaps by the same rope passing under and over, necessary pulley wheels, &c.), the second well being another 20ft., or sometimes even 50ft. or 100ft. deep. These are the wells wherein the danger lies, and yet, after a little while, you become thoroughly at home in such wells. It requires confidence and great skill in making proper examination and preparations every time you enter a well.

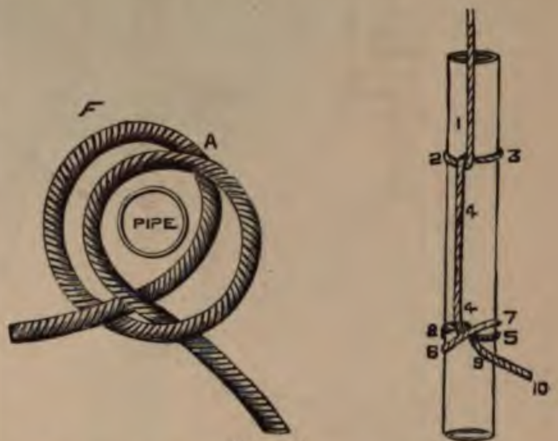
Sometimes it happens that you work off ladders from stage to stage, &c. When such is the case, take care that you fix the ladder safely, and that the *stages are sound*, for it is not at all an uncommon occurrence to find the stages of old wells, and, indeed, in many new wells, not properly ventilated, to find the timber rotten through a kind of mildew or wet rot, and for such timbers to give way under one's feet, to the horror and dismay of the person descending. My advice is, never to descend into a well from stage to stage on ladders, unless you are quite certain that the stages are safe. I also contend that all stages should be of iron, granite, or gun-metal. Such stages will be illustrated as we proceed with our deep-well pumps; but before entering upon this it will be best to explain the simpler kinds of pumps to fix.

Fixing Jack or Suction Pump.

We will now proceed with the fixing of the "jack or suction-pump." Again refer to Fig. 810. Here you have the well say 18ft. deep, with one stage, as shown at W. In this case, the stage is an oak plank say 3in. by 9in. wide, having a hole bored, and a little counter-sunk on the top side; the hole should pass through the centre, but nearer to one end than the other, say 8in. from the brick-work. Now prepare your suction-pipe for nailing a block of oak, say 6in. square or round, and 12in. long, having one end shaped as shown at oak block, Fig. 810, to enter the end of the suction; then bore a quantity of $\frac{3}{8}$in. or $\frac{1}{4}$in. "blast holes" round the bottom of the pipe, as shown at blast holes. Bore enough of them. If you have a 2in. pipe, how many $\frac{1}{4}$in. holes will you require? Answer, 16. Because you have a 2in. hole, and the square of 2 being 4, you require the $\frac{1}{4}$in. multiplied by 4, which equals 16. Then bore half as many again, and your pump will work easier, because in the 16 holes the friction will be sixteen times as great as through the 2in. pipe.

Some plumbers, instead of using bored blast-holes, simply cut three or four long cuts with the chipping knife; these holes allow anything to get out of the barrel into the well, should it fall in when repairs are going on, &c. This, in some cases, answers better, though blast-holes are generally used. The block should not be fixed before the pipe is put through the holes in the stage; do not fix your block before your blast holes are bored, or perhaps small bits of lead will get into the pipe and cannot be got out, and which will work up and interfere with the sucker valves action.

The flanges may be cast, or if too much trouble to cast, cut open a piece of your suction-pipe for the flange. Say the pipe is 2in., then your piece of pipe for the flange 6in. long, and with the chipping knife cut it down, and after this, with the turnpin driven through, the piece of pipe is easily opened. Flatten it out, and then cut or burn, with a red-hot plumbing-iron, or otherwise, a hole through the centre, large enough to slip over the suction-pipe. Now,



Figs. 816.

with a piece of sash-cord form the knot, as shown at Fig. 816, making two half-hitches, and slip them over the end of the pipe as shown. Bring the ends together, and with the longest end form one half-hitch (which is really only one of the former hitches, as shown at 1, 2, 3, 4, Fig. 816) over the end, say about 12in. down the lead pipe; then with the aid of one man on top of the well holding up the pipe you enter the well. Now slip the end of the suction-pipe through the oak stage, and with copper nails nail on the block on the suction as shown at Fig. 810, then lower it and slip the lead flange over its end, then turn the flange over for a taft joint (see Figs. 149, 150, and 151), get a nice wad of paper or something to stuff into the pipe. Next prepare the joint A, Fig. 810, of the pump for an under-handed or other joint, as shown at Fig. 122, and wipe on the length A to F ready for fixing the pump, the nozzle of which should not exceed 3ft. in height, or above the ground. The back should be fixed against a wall, or if no wall is near fix it upright, and make the flange joint W, Fig. 810; but take care that no lead shavings or other hard substances get into the pipes. It is now ready for the carpenter to make and fix his frame to, as shown at Fig. 817.

Wood Work or Frames for Pumps.

The supports, A, B, are, say 3in. deal or other timber, hard wood is best (oak), let down into the ground, and having pieces or grooves cut out to receive the head, as at E to G, and F to J, this supports the pump and steadies it: the back is next nailed on, and then felt, &c., put in against frost, and then the front is fixed, from the nozzle upwards with screws, or sometimes a door is used. Should there be no regulating head, then the flanges F C, Fig. 804, fit into the grooves E, G. F, J, Fig. 817, which keeps the pump upright and steady. The slot K, as also the hole B for the lever and pin, may be prepared before the frame is fixed; but care must be taken to fix this lever slot in its proper position to work the bucket-rod. Plumb over the centre of the barrel. Sometimes these jack pump bucket-rods are worked with a rod and sling, as shown at Fig. 845, but with the stay or guide fixed on plank.

I have already explained how to set the sucker-box, and the various kinds of pump buckets. Some plumbers may ask, What is the use of the cock and pipes, F, G, H, Fig. 810? The answer is, to allow the water to run back into the well during the winter. There are many ways to get over this difficulty [see Fig. 820], here the bucket comes down on the spir F, which tilts the valve when required. Now suppose everything to be finished, and water required in the pump: you will have first to fill the barrel with clean water, and quickly work the handle, and

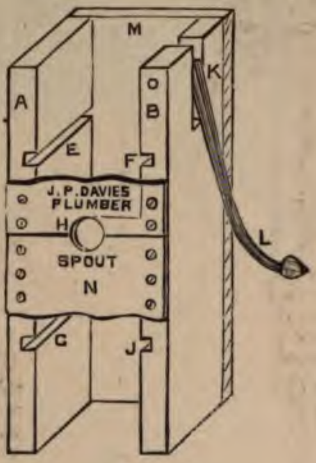


FIG. 817.

in a moment or so you will feel the handle to work a little heavier and heavier, until the water is seen running out of the spout or nozzle. Keep up the pumping for a minute or two: this will bring any small substance up from the sucker-box, which by accident may have got there. Of course, nothing should be there, but sometimes it happens that there is Now stop pumping, and notice whether the water dribbles a long time after the pumping has ceased. If it does, it is sure to be "right." If not, "the sucker-box is not right."

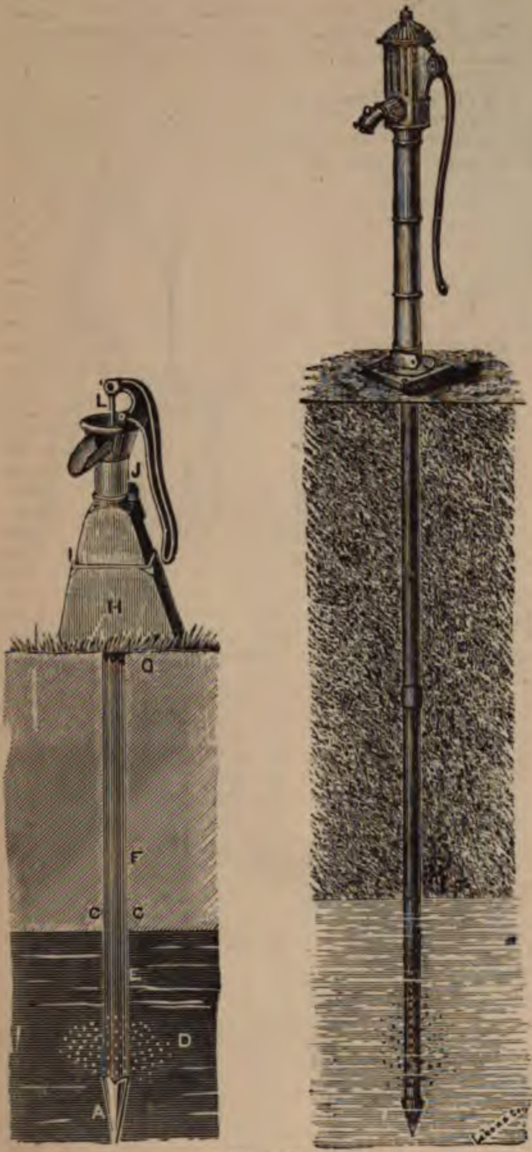
Repairing Pumps.

Something is under the valve, the box may not be properly cemented in, or the valve is bad, the leather may be a bad one, or half-a-dozen other things. Something is the matter; the pump "loses water," "it runs back." In this case, take out the bucket, get the pump hook, E, F, A, B, Figs. 8 and 9, screw the screw into the lead clack, as shown at Fig. 785. Now this clack will not move, because it has been properly set, or cemented in. If it is loose, it is bad setting, by reason of not being properly knocked down, or not sufficient fat or tow used, and will easily be pulled up. Or, perhaps, the leather has not been properly nailed on the sucker-box. If the latter is the case then the clack will be loose, if so it is easily drawn; it will be loose in the bottom of the barrel, and the sucker or pump-hook must be used carefully, or you may spoil the face of the sucker-box. Always try for this by pushing the point of the sucker-hook lightly over the top of the clack. Perhaps all will be firm; if so, screw the screw into the clack, screw it tightly in, and do not screw the rod round without pressing well on the top, nor too far. If it is hard to draw, the clack is nailed on properly, and requires a kettleful of hot water poured into the barrel; half fill the barrel and let it stand for a few minutes. Now pull the clack open, let the best part of the water run back, and shut it again; this allows the water to run through, and warm up the mutton suet or other cement. Now pull the clack up. Generally the box and all will come, as it should, together, but at times the clack comes away from the box; if so, after the clack is got up, as before directed, put the pump hook carefully through the hole in the sucker box, until the hunch or hook is below the bottom of the box, as shown at C, E, F, Fig. 9. Now give a good pull, and the thing is up; but perhaps it won't come; then get a piece of dog-chain, or a strong piece of sashcord, and threadle it through the eye B, and prize up the hook with the aid of the handle or lever of the pump, or substitute a lever as best you can. The box is now up, and perhaps it is found that a lump of brick, a piece of solder, or something, is brought up with it, or that the face of the box or leather is bad, or else nothing is found. If so, take a pail of water and suddenly empty the lot down the pump; this will wash any small stuff through the blast-holes and into the well. I always do this before I set a sucker-box, especially in a new pump *not having a tail-valve.* Now, as before explained (at sucker-boxes, fitting and setting; lead clacks, pump buckets, &c.), prepare your clack and sucker-box: then set it again, and fix the pump-bucket, fill up the pump-barrel with clean water, and "fetch the water." It is now all right, and the pump "*holds water*," meaning that the pump is "sound." Perhaps something else is the matter, for after "she" has stood for an hour we have to pump for a minute or so before the water comes, and at first it is all froth, or on a foam. "She draws air," that is, there is a pinhole in the suction-pipe, or the joint A, Fig. 810, is bad, perhaps porous. If the cock F is used, perhaps, it is there: whatever it is, it must be found. For this purpose, the ground must be stripped off the pipe, and the well uncovered. If the pipe is an old one most likely the chemicals held in the earth have eaten holes into the lead, or twenty other things may be wrong. The pin or air-hole, however, must be found and soldered up, or a new suction-pipe fixed.

As you proceed with the different classes of pumps, you will more readily understand the repairs which will come quite naturally to you; hence why I place so many kinds of pumps before my young reader, for, though I say so, I do not expect you will ever see a quarter of the pumps I show, because it will involve almost a lifetime to come across such a variety.

Tube Well and Pump, or Abyssinian Pump.

This kind of pump was much used by the English soldiers during the Abyssinian war, hence the name. Figs. 818 are illustrations of these pumps, showing the suction A, E, F, driven into a water-bearing strata at A, D, E; it will be plain that if you drive the tube G, F, E, A, through the soil, &c., as explained in the geological woodcut, Fig. 771 or 772, or into a water-bearing stratum, as shown, you can pump up the water in due proportion to the moisture of the said strata at the blast-holes, and that by continual pumping the vacuum produced by the suction will cause the water to flow towards the blast-holes. Such is the construction of the tube-wells. I may add that, however useful these wells may have been found in times of war, &c., you must not at all times expect such wells to yield that plentiful supply which can be obtained from the digging of a properly-constructed well, nor can you expect these kinds of pumps will work with the same ease that the [illegible] jack pump does when fixed in an ordinary well [illegible] Simply because in the tube-pump you are [illegible] on the



Figs. 818.

interrupted pressure of the atmosphere for assistance, and which is hindered by its passing through the different strata of the earth before it can get to the water near the blast-holes, and to which to a great extent the tube well owes its source of supply. I have shown two pumps, the tallest having a clack cleansing door at bottom, the other or short pattern being a short wide barrel.

Abyssinian Tube Well Driving.

he well as ordinarily used is not intended for or solid stone foundations, but it is capable ery hard and compact soils, and can also be successfully driven through the chalk, breaking through the flints which may obstruct its passage downward; but when rock or stone is reached and has to be pierced, special means of drilling have to be provided for it. When coming upon rock or stone, the best plan is to pull up the tube and try in another spot; this applies also when deep beds of clay are driven into, for it is better to pull up the tubes and go a little distance off and test again, as in many cases by so doing water will be found.

Figs. 819.

Driving Tube Wells.

Generally speaking two men are necessary for the work, but as a rule plenty of hands are to be found willing to assist in the glorious work of obtaining drinking water by wells. The tubes, &c., at Figs. 819 too well illustrate the work to need further comment, excepting just the technical points. The "clamp" should be firmly fixed upon the tube, and the sliding rod fixed for guiding the monkey or driving weight, which latter is generally actuated by ropes running over the pulleys as shown, and with a movement of say 5ft. or 6ft., according to the depth, hardness of the ground, &c. One man holds the tube just for a start, the other works the monkey or

other implement necessary for driving the tube. Care should be taken to fix the tube perpendicularly. Having the tube fixed plumb and to stand by itself both men work away at the driving, and if clamps be used to clasp the pipes they should be loosened and refixed about every 2ft., and the pulleys adjusted accordingly. If the ground be very hard it will be found best to fix the clamps about 18in. or less from the ground. Of course you drive away at these tubes and so lengthen them by screwing others on until the work is finished; and take care the joints are made quite sound as you progress with the driving. Take frequent tests with a plummet for the water, and when the tube is driven into the water bearing stratum, the pump should be applied as shown at Figs. 818. Of course you will require to prime your pump in the usual way by throwing a little water into the barrel. You may become impatient over this job, especially if the stratum be a close or compact one. The pump must be worked quickly and with short strokes at first.

The water at first is more or less muddy, according to the nature of the stratum, but by steady pumping it will in time clear up and be fit for use.

Should the ground through which the tube has been driven prove of such a clayey or sandy nature as to find its way through the perforated tube to any extent, so that when the pump is put on, the water cannot penetrate through the accumulation in the tube, it is necessary to use the small clearing-out tubes. A sufficient number of these must be screwed together to reach to the bottom of the well tube. The reducing socket has to be screwed on to the upper end of the small tubes, and the pump is screwed into this socket. This done, the water which has been poured down the well tube will by degrees moisten the earth, which can be pumped up through the small tube, while fresh water is being poured down the well tube; until, by this means, all the earth which has accumulated in the tube has been cleared out. When this has been accomplished, the small tubes can be withdrawn, and the pump having been screwed on to the well tube, the well is complete.

To facilitate filling the well tube, for the purpose of cleaning it out, a funnel is used, which can be screwed on to the well tube.

It might also happen that the well tube may have been driven through the water-bearing stratum; should this occur, the well tube can be readily drawn up to the water stratum again.

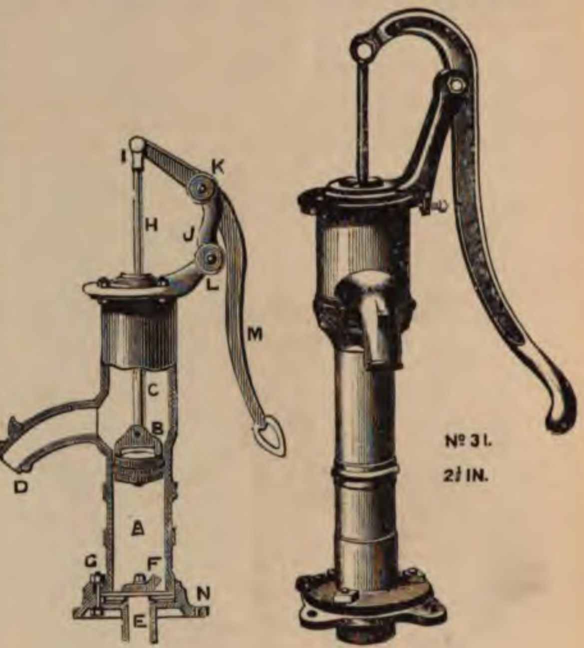
In driving the tube, should rock be met with, or from any other cause it is found necessary to withdraw, this may be accomplished by fastening the clamp to the tube a few inches from the ground, and by applying a lever at each side, raise it a short distance, lowering the clamp after each successive lift. Another plan of withdrawing the tube is to put the monkey on the pipe the reverse way to what it is when driving the well, and then fasten the clamp on the tube also the reverse way, about one foot above the monkey. A man on each side pulls up the monkey against the clamp, and drives it upward out of the ground; when all the tubes are withdrawn they may be redriven in another spot. In withdrawing the tubes, each length must be unscrewed as it is raised.

In some very solid strata it is necessary, in order to open up the water-way to the well tube, to use a force-pump on the top of the tube, and by forcing water down under great pressure the strata will be forced, and water communications opened to the well tube; and when water flows freely down the tube without forcing, the operation is generally complete. This application of the force-pump is also of great service when the well may be in a "pot" of clay, in the immediate vicinity of water; for by forcing water down, a water-way is opened to the water-bearing stratum, and a good well is thus obtained.

Cheap Pumps.

Cottage or Iron Jack-Pump, and Tilt Sucker-Box Valves, for Places exposed to Frost, Theft, &c.

For this kind of pump refer to Fig. 820, with and without rocking standard. This pump is used on account of its cheapness, especially by gardeners. The figure on the right is cheaper than that on the left which has a rocking or



Figs. 820.

Fig. 821.

vibrating standard J, which is hinged at L, K; the pump-rod works through a hole in the top, so that children cannot put stones, &c., in the barrel. E is the suction-pipe, F the tilt-valve for emptying the barrel in winter, which can be fixed open by lowering the bucket to the bottom of the barrel in such a manner that the bottom of the bucket will rest upon the spur F of the valve. This is very handy in the winter. The pump is screwed down upon planks, &c., as at N. Fig. 821 is the same class of pump, but fitted with a sucker box, and longer in the body for courts and alleys.

Overhanded Action Pumps.

These pumps are made by J. Fell & Co., for fixing in places where the ordinary pump handle cannot be worked, or where it would be in the way, see Fig. 822. These

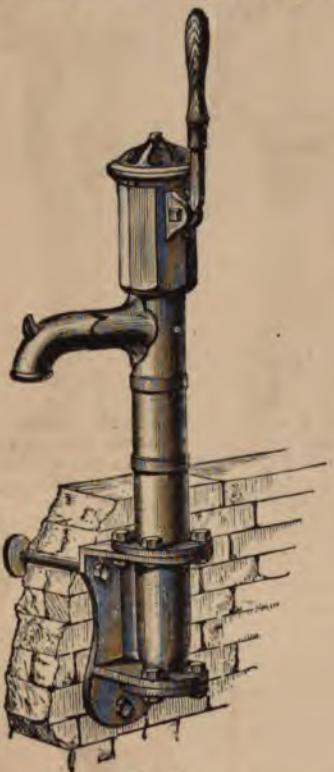


FIG. 822.

pumps may be had to fix on a wall as shown, or the body may be as at Figs. 821, 823, &c.

Full-sized Iron Pump, with accessible Sucker-Box Plate.

In this pump, Fig. 823, is to be seen a valve box B, covered by a plate K, and which is very convenient when repairing the sucker-valve. The bucket, as may be seen, works within the barrel A, and has a long stroke. Such pumps are handy where there is much knocking about, but are bad for winter work on account of the frost. Of course, the same pump may be fitted with valves fixed direct under bucket. Such valves are shown at N and M in the gram. These valv [illegible] fixed between flanges, a sucker-box n [illegible] as at N.

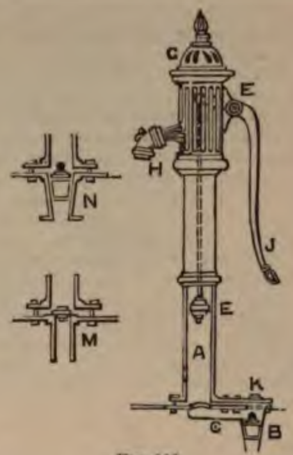


FIG. 823.

Party-Wall or Double-Handle Pumps.

These pumps are used for double dwelling-houses having party-walls, the pump being built in the brickwork and having swinging handles on each side, as shown at C D, Fig. 824. The spout of the pump, A, Fig. 825, runs into a kind of sliding dish, or trough B, Fig. 825, the bottom part of which has a partition, and two compartments with nozzles as shown at D, F; this sliding dish receptacle rests upon the brickwork or wall G, and is worked as follows. Suppose the people on the D side of the wall require water, the slide B is right for the water to run from the nozzle into the slide, and from thence into the compart-

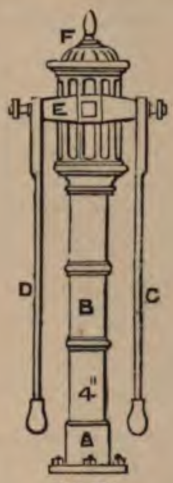


FIG. 824.

ment C, and out at D. But suppose that water is wanted in the compartment E, then the slide B must, with the hand, be pulled by the handle K over the partition, so that the slide may empty into the compartment E, when the water will run out at the spout F. Of course it is not necessary that the well should be under the wall, but may be at any distance away, as shown at Fig. 810, 823; and when, if deep, it must be worked by rods, &c., to be hereafter explained, and for which see E, F, G, H, and M, N, O, P, Q, Fig. 888, &c.

Floating Pole Pumps; Fixing Iron Pumps; Wood Stages.

For this class of pump refer to F H, Figs. 826 and 827. This is an iron pump having a floating instead of a balanced pole F, for actuating the bucket D, and will be readily

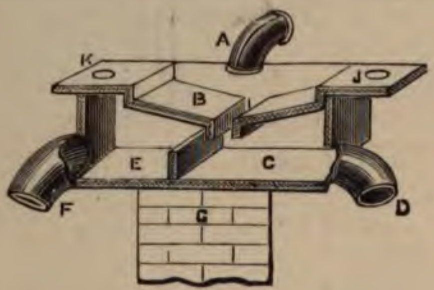


FIG. 825.

understood from the illustration and the following description. Most of the old wooden pumps had these floating poles.

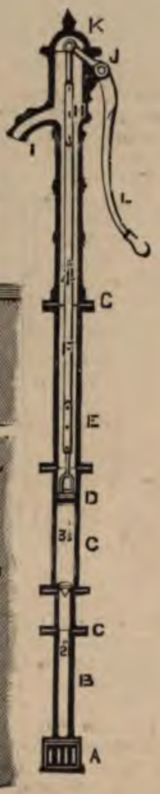


FIG. 827. FIG. 826.

A, Fig. 826, is the strainer or blast-holes, which must be fixed upon a good solid foundation, unless otherwise fixed upon stages, or at the top of the well, which is sometimes done by cutting two semicircular holes in two 6in. by 9in. or 11in. pieces of timber, and by fixing the flange G of the pump, as at F, Fig. 827, between these timbers (for this see A B, C D, Fig. 828). Now suppose all to be screwed together, as illustrated in the above diagrams, the bottom or barrel part being supported or steadied by the stage C, a plan of which is shown at Fig. 828; A C is the main stage and B D the clip block, which is bolted to the main stage with the bolts A, B, C, D. There is an advantage in using such stages as these: the stage is not weakened by boring a large hole through the centre of the wood, and another is that they hold the pipe as firm as you may choose to screw the block to the main stage. Of course, such stages may be of iron or gun-metal. Having everything in the well right, next provide the pump-pole, which

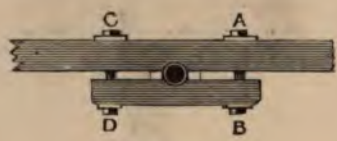


FIG. 828.

should be at least from 1½in. to 2in. diameter, made of oak, or other good lasting material. Fasten the forks of the pump-rod to the pole, as shown at E, Fig. 826, and to the bucket as at I, J, Fig. 798; and also the coupling at H to the pump handle. It may happen that an extra coupling will be required to connect two or more poles together, or this may be done with two iron plates with the pole bolted between them. Having the lot the exact length, and the sucker box fixed, proceed to lower the first pole, then the next is bolted on, and the next, until the desired length is obtained. Now pour some water into the pump and work the handle, as before explained in jack-pumps.

The pumping at first will hang very heavy on the hand, and most likely cock the handle, but as the water rises up the pump, so the rods will float, and the whole thing become light on the hand. Such pumps generally work lightly, and will last a long time; but it will readily be seen that they cannot throw water above the handle; but happily we can with another kind. Such a pump I made and fixed thirty years ago at Hanger Hill, and is illustrated at Fig. 829. Here is a lead pump barrel reaching from bottom stage C to the top. Of course, the ordinary clack sucker box may be used in conjunction with this bucket and floating pole. It is easily repaired and works with freedom, either from a frame or any of the handles to be hereafter referred to. See Figs. 868, 877, 881, &c. This pump, Fig. 829, is known by the name of a lift and force-pump; and is an example of doing away with the rising main clack or valve, and works like a beer engine pump. Now it is time to consider what will be the pressure upon the sides of the barrel and bucket of pumps. In this case suppose the well to be a deep one; then you must use a pump-barrel of suitable size for the easy working, and the materials of proper thickness to withstand the pressure. Take into account the height of the pipe or rising main which is carried above the top of the well, because this, as a matter of course, adds extra pressure to the water within the pump-barrel.

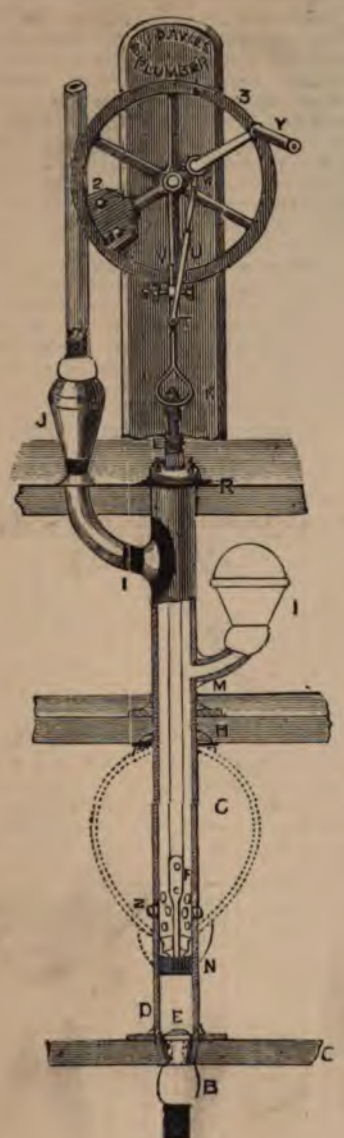


FIG. 829.

Pressure Table for Pumps and also for Atmospheric Pressure and Weight of Water per square Inch·

The pressure of 15lb. to the square inch may be understood from the following simple illustration, but, for our purpose we will say 15 lb. atmospheric equals a 30ft. ...n of water, see further on. Suppose you have a ...ctly 1in. square as at B, Fig. 830, and a square ...und in or otherwise) made to fit air and water- ... the tube; now say that this square weight ... 15lb. on B. Let from A, to B, be 30ft. Now fill this pipe with water, and the weight at B will just balance the column of water. Here the 15lb. weight is also balanced by the column of water. Suppose the weight to be 1lb., then only 1lb. pressure within the tube is required to buoy up the weight. Now suppose that instead of a square tube we use a round one, the area of which is smaller than the square. What will be the atmospheric pressure (supposing it to be 15lb. to the square inch) upon the 1in. circular pipe, not taking decimals into

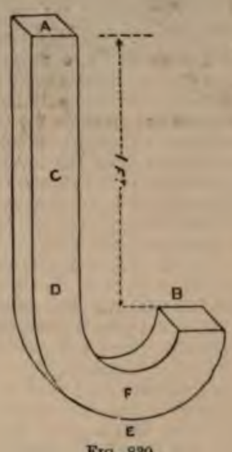
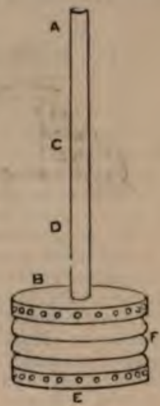


FIG. 830.



HYDROSTATIC PARADOX See page 398.

FIG. 831.

consideration? The answer is, nearly 12lb. Therefore, a round 12lb. weight *only* is required in a circular pipe to withstand the 15lb. *to the square inch* pipe: or, in other words, connect the bottom of the round pipe with the bottom of the square one, and the square 15lb. weight, and the round 12lb. weight will stand at one water level. This being the fact, it is easy to find the difference between the square and the circle, at least, near enough for our purpose.

Circles and Squares, Relationship of.

The following are simple rules for doing this:—

Rule 1. Multiply half the circumference by half the diameter for the area, as for example, suppose the pump to be a 4in., say the circumference is 12in. (for a nearer calculation say 12½in.), half of which is 6in., this multiplied by half the diameter, which is 2in., will give 12in., the area near enough for this purpose.

Another more precise rule is to multiply the square of the diameter by ·7854 for the area.

Say, roughly speaking, that the area of a 4in. pump-bucket is 12in., that a column of water has to be lifted to the height of 60ft., and that the pressure required is 30lb. to the square inch: here we have to multiply the 12in. by 30lb., which will be equal to 360lb. Here you require a dead lift of 360lb., to say nothing of friction (it is this friction, &c., which make it never come out in practice), before you can overcome the resistance of the column of water, or, in other words, lift the bucket. The ordinary leverage of a pump-handle is from 5 or 6 to 1, and the power exerted upon the handle of a pump by an ordinary working man is 25lb., that is to say, if he is to work *continuously*, will not exceed 25lb. pressure on the handle. Now multiply the 25lb. by 6 times the lever, and we get 150 lb., not half enough to work the pump.

Reduce the column of water to 30ft., or, for our purpose, to 15lb. to the square inch; then 12in. being the square of the pump-bucket, multiply the 15lb. by the area of the pump-bucket, namely, 12in: here we get 180lb. This will be quite enough for any man to lift, and too much for continuous working (*it must be remembered that pumps are worked all day by hand, and it is here where the hard work comes in*), taking friction into consideration: then it follows that it would be useless for us to fix a 4in. pump 60ft. deep, and to expect one man to work it.

Selecting the Sizes of Pump Barrels for different Heads of Water.

In order that the pump shall work easily, a proper-sized barrel must be selected and employed. The theory of this is explained above, but the following tables will be found useful, as I have worked the table out suitable for wells of different depths to be worked by an ordinary pump-lever of about 6 to 1. Some pump-makers give the leverage as only 5 to 1. It should be observed that the sizes of the barrels should never exceed those given for the column of water, but rather under. You will notice that the depth of a well is not all that is to be measured, but from the water-level in the well to the place of its *discharge*. Of course, perpendicular or vertical height only, is to be taken into consideration, save and except the friction and *momentum*, the latter of which plays an important part in pumps worked by hand and leverage, especially those not having air-chambers. In fact, so much is this the case, that I have on many occasions worked the ordinary jack pump without the sucker-valve ever closing after it has once opened until the pump is at rest. The cause of this is, that the water had not sufficient time to stop, and therefore passes through the pipes in a continuous stream. This can very easily be done with pumps having long lengths of horizontal suction. Should you like to see the same thing, work the handle with very short strokes, and very quickly, like so many snatches; the momentum of the water knocks up the bucket-sucker, and the sudden snatch being quicker and faster than the flowing column of water, the bucket-valve again closes, and your power is again applied to lift the water onward through the pump and pipes.

This being so we will now for arriving at its momenta, suppose that a column of water 20ft. long, weighing 100lbs., to be moving at the rate of 10ft. per second, and by a valve instantly stopped, this would strike a blow in proportion to the above weight of water multiplied by its speed per *second;* and it must be observed that you must make your calculation according to the laws of mechanics; for example, if the velocity of a body be represented by 5, and its weight by 6, its momentum will be 30, and so on, which will explain the clack above not closing in time.

Atmospheric Pressure, and Specific Gravity of Water.

Also the weight of water per foot in a vertical pipe one inch square. I have always said that the atmosphere exerts a pressure of 15lb. to the square inch, because this is the English standard, and say again for convenience sake that a 30ft. column requires 15lb. to balance it. This we plumbers generally work to; but although we work to this rule, it is not mathematically correct, though it is very suitable for mental calculations, and may be said to be near enough for our purpose. The real thing is as follows: for correct working we must first study (for atmospheric pumps) the density of the liquid and state of the barometer. Say that it now stands at 30in., the real weight of atmosphere is 14lb 12oz.; some would go nearer and say 14·73lb. on the square inch. Now should it rise or fall one inch, what will be the difference in weight? The answer is 7¼⅗oz. *The weight of the water per square inch one foot high.* This being the fact, let us suppose that we have a common jack pump which has to raise liquid whose specific gravity is 1·2 to the height of 14ft.; let the area of the bucket be 8in., and the lever 3ft., with a power of 12 times, being at least twice the ordinary power—what will be the answer? 4lb. 13⅞oz. But this nicety of working is no practical use to the plumber, unless it is for examination purposes.

Examine the first pump in the table. Here is a 7½in. pump, which is lifting water 10ft. at the rate of 2,158 gallons per hour, expending a weight of 191lb. 9in. high 25 times every minute. Now take the last figure in the table, and you will see that the water has to be lifted 150ft., consequently a smaller pump-bucket must be used. This requires more power to work the pump than was necessary for the 7½in. pump. The 2in. pump-barrel requires a power of 203lb.; but notice what an enormous power a 7½in. pump would require for a well of this depth—no less than 2,868lb. (see table of diameter of pumps), and if worked at the same

P. J. DAVIES'S PUMP TABLE (REGISTERED).

Height of Water to be pumped above the surface of water in well by one man.	Size of pump-barrel in inches, suitable for one man to work at different depth wells, or height of water to be pumped above the level of the water in well.	Quantity of water raised in gallons per hour, at 25 strokes per minute.			Resistance or weight of the column of water to be lifted at each stroke of the bucket by the pump-handle. Friction not taken into consideration. Maximum figures must be read.	Pressure in lbs. to be exerted on the handle, or nearly so. Leverage 6 to 1 without friction.
		With a 9in. stroke, one man required.	With a 12in. stroke, two men required.	Feet.		
ft.	in.	gal.	gal.	ft.	lbs.	lbs.
10	7½	2158	2877	10	191 heavy	31
10	7	1880	2507	10	166	27
10	6½	1621	2162	10	143	23
10	6	1381	1841	10	122	20
15	5½	1161	1548	15	152	25
20	5	959	1279	20	170	28
25	4½	777	1036	25	171	28
30	4	614	819	30	163	27
35	3½	470	627	35	145	24
40	3½	470	627	40	166	27
45	3½	470	627	45	186	31 exact
50	3	346	462	50	152	25
55	3	346	462	55	168	28 exact
60	3	346	462	60	183	30
65	3	346	462	65	198 heavy	33 exact
70	2½	240	320	70	148	24
75	2½	240	320	75	159	26
80	2½	240	320	80	169	28
85	2½	240	320	85	189	31
90	2½	240	320	90	191 heavy	31
95	2	154	204	95	129	21
100	2	154	204	100	136	22
110	2	154	204	110	149	24
120	2	154	204	120	163	27
130	2	154	204	130	176	29
140	2	154	204	140	190 heavy	31
150	2	151	204	150	203 too much	33

DIAMETER OF PUMP TABLE OR WATER PRESSURE TABLE.

Vertical Height from Bottom, in feet.	Lbs. per sq. in. at 15lbs. to the 30ft. column.	Diameter of Pumps.							
		2 inch	2½ inch	3 inch	3½ inch	4 inch	4½ inch	5 inch	5½ inch
ft.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
10	5	13.596	21.244	30.591	41.584	54.383	68.830	84.977	102.821
20	10	27.19	42.48	61.18	83.16	108.76	137.66	169.95	205.64
30	15	40.78	63.73	91.17	124.75	163.15	206.49	254.93	307.46
40	20	54.38	84.97	122.36	166.33	217.53	275.32	339.90	411.28
50	25	67.98	106.22	152.95	207.92	271.91	344.15	424.88	514.10
60	30	81.57	127.46	183.44	249.50	326.30	412.98	509.86	616.92
70	35	95.17	148.70	214.13	291.09	380.68	481.81	594.83	719.74
80	40	108.76	169.95	244.72	332.67	435.06	550.64	679.61	822.56
90	45	122.36	191.19	275.31	374.25	489.37	619.47	764.80	925.38
100	50	135.96	212.44	305.91	415.84	543.83	688.30	849.77	1028.21
110	55	149.55	233.68	336.50	457.42	598.21	757.13	934.74	1131.03
120	60	163.15	254.92	367.09	499.01	652.60	825.96	1019.72	1233.85
130	65	176.73	276.17	397.68	540.59	706.98	894.79	1104.70	1336.67
140	70	190.34	297.41	428.27	582.17	761.36	963.62	1189.68	1439.50
150	75	203.94	318.66	458.86	623.76	815.74	1032.45	1274.65	1542.31
160	80	217.53	339.90	489.60	665.14	870.13	1101.28	1359.63	1645.13
170	85	231.13	361.14	520.04	706.93	924.51	1170.11	1444.61	1747.95
180	90	244.72	382.39	550.64	748.51	978.90	1238.94	1529.58	1850.77
190	95	258.32	403.63	581.23	790.10	1033.28	1307.77	1614.56	1953.60
200	100	271.92	424.88	611.82	831.68	1087.96	1376.60	1699.54	2056.42
		6 inch	6½ inch	7 inch	7½ inch	8 inch	9 inch	10 inch	12 inch
ft.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
10	5	122.365	143.611	166.267	191.195	217.539	275.326	339.909	489.466
20	10	245.27	287.22	332.53	382.39	435.07	550.65	679.82	978.93
30	15	367.90	430.83	498.80	573.58	652.71	825.97	1019.72	1468.39
40	20	490.54	574.44	665.06	764.78	870.15	1101.30	1359.63	1957.86
50	25	613.17	718.05	831.33	955.97	1087.70	1376.63	1699.54	2447.33
60	30	735.81	861.66	997.60	1147.17	1305.23	1651.95	2039·45	2936.79
70	35	858.44	1005.27	1163.87	1338.36	1523.77	1927.28	2379.36	3426.26
80	40	981.08	1148.88	1330.13	1529.56	1740.31	2202.60	2719.27	3915.72
90	45	1103.71	1292.50	1496.40	1720.75	1957.85	2477.93	3059.18	4405.20
100	50	1226.35	1436.11	1662.67	1911.95	2175.39	2753.26	3399.09	4894.66
110	55	1348.98	1579.72	1828.93	2103.14	2392.92	3028.58	3739.00	5384.12
120	60	1471.62	1723.33	1995.20	2294.34	2610.46	3303.91	4078.90	5873.58
130	65	1594.25	1866.94	2161.47	2485.53	2828.00	3579.24	4418.81	6363.05
140	70	1716.90	2010.55	2327.73	2676.73	3045.54	3854.56	4758.72	6852.52
150	75	1839.52	2154.16	2494.00	2867.92	3263.08	4129.89	5098.63	7342.00
160	80	1962.16	2297.77	2660.27	3059.12	3480.62	4405.22	5438.54	7831.45
170	85	2084.79	2441.38	2826.54	3250.31	3698.16	4680.54	5778.45	8320.92
180	90	2207.43	2584.99	2992.80	3441.51	3915.70	4955.86	6118.36	8810.40
190	95	2330.06	2726.60	3159.07	3632.70	4133.24	5231.20	6458.27	9299.86
200	100	2452.70	2872.22	3325.33	3823.90	4350.77	5506.52	6798.2	9789.32

rate as the one on the first line of table—namely, 25 strokes per minute, it would only throw up the same quantity of water; that is, with a 9in. stroke, 2,158 gallons, and with a 12in. stroke, 2,877 gallons.

I think I have said sufficient on this subject to enable my readers to know and thoroughly understand what sized pump to select under the many different heads of water, and in such pump work as the plumber is required to undertake, and shall conclude this part by giving two tables owing the power required to work a pump from 2in. bore in. for wells rangi ft. to 200ft. deep; also at the square ach sized barrel; this table is also handy for ascertaining the pressure per square inch on vertical lengths of piping.

Water Weight and Capacity Notes.

A cubic foot of soft water weighs 62·425lbs., and contains 6·2355 (approximately 6¼) gallons; 1 gallon of such water weighs 10lbs., and contains 277·274 cubic inches. Gallons × 0·16 = cubic feet. 1 ton of water = 35·9 cubic feet = 224 gallons; 1 cwt. of water = 1·8 cubic feet = 11·2 gallons. Each quarter-inch of rain-fall gives 13 gallons on every 100 superficial feet of area.

Water, Weight of.

Before examining the water pressure table it will not be out of place for me to draw your attention to an easy, and simple method for calculating water pressure, per square inch; first remember that a cubic foot of ordinary cold water is generally taken to weigh 1,000ozs. Now on the base of a square foot there are 144 square inches, therefore, if you divide the 1,000ozs. of water by the 144 this will give you the exact weight of one vertical foot, whose base is 1in. square, and which is $6\frac{17}{18}$, or 7oz. nearly.

Example: 144)1,000($6\frac{17}{18}$, or 7 nearly.

$$\begin{array}{r} 864 \\ \hline 136 \end{array}$$

$$\frac{136}{144} \div 8 = \frac{17}{18}$$

For the area of pumps or pipes see Pipe Area Table.

Table of Lengths and working strength of lead pipes. Also see Lead pipes, Strength of (in Town Water Supply).

I shall now here continue my table on the strength of lead pipes of large sizes, but for the smaller sizes see page 36 (Table of Lengths and Working Strength of Lead Pipes). This table will give you the strength of lead pipe suitable for pump-work at different depths, &c., and is the result of practical observation, and of long and careful watching whilst at work, experimentalising, &c., and consequently may be relied upon by the workman. Take notice, these pipes are made of soft Spanish lead, the *harder* the lead the greater the strength, and tested when quite *cold*, and have not been subjected to powerful jars, but simply tested under a powerful force-pump. I should here remark, then, when fitting up pumps in wells, &c., it is not at all necessary that the pipes should be of uniform thickness throughout the length, but they may be worked as in the table. If no air-chamber is used, use *two* extra substances to compensate for the jars, &c. A table of cast iron pipes for pumps, &c., may be seen under the head of Iron Pipes, Strength of, Weights, Thickness, &c.

Hydrostatic Paradox.

I may here observe that I have made lead pipes ½in. thick for conveying sulphuric acid where there was only 20ft. pressure, and in the year 1890 fixed over one mile of such at Morfa works, Swansea, the sizes were 3in. diameter and in 10ft. lengths, weight of each length 3½cwts. Also a quantity of 1½in. pipe, ½in. thick for the acid injectors, &c., so that the thickness of lead pipes must not always be governed by the pressure. Having explained what is meant by the 15lbs. to the square inch atmospheric pressure, also what constitutes water pressure per square inch; there yet remains something to be explained, and that is, why is it that we get such enormous weights upon our pump-buckets and yet the rising mains are not half the size of the pump-barrels. This can be explained by the following experiment: Let A D, Fig. 831, be a 1in. square pipe 30ft. high, filled with water, here, according to our former calculations (of ½lb. to equal 1ft. column of water), we should get 15lbs. to the square inch, but let the top of the bellows B, E, F, be equal to 144 square inches, what pressure would there be exerted upon the whole of this bellows top?

The answer is simply 15 × 144 = 2,160.

Here it is evident that it is not the size of the pipes which gives the pressure per square inch on a given sized pump-bucket, but the vertical height simply, because the nature of fluids is to press equally in all directions, that is, the water presses upon the bottom, sides and top with equal force save the difference in the vertical height of the water, which in this case need not be taken into consideration.

Lead Pump-Pipe Table, Safe for Pressures from 10ft. to 550ft. or from 5lb. to 275lb. to the Square Inch.

For a pump.	Diameter of bore in inches.	Safe for a column of water in feet.	Weight of length of 12ft.
in.	in.	ft.	lb.
2½	1¼	25	36
2½	1¼	60	42
2½	1¼	120	48
2½	1¼	250	52
2½	1¼	500	60
3	1½	20	36
3	1½	50	48
3	1½	100	55
3	1½	250	72
3	1½	400	84
8	1½	550	96
3½	1¾	100 (not recommended)	72
3½	1¾	200	84
3½	1¾	300	96
4	2	15 (will stand 25)	36
4	2	50	56
4	[illegible]	80	64
4	2	100	72
4	2	200	84
4	2	300	96
4	2	400	112
4	2	500	120

For a pump.	Diameter of bore in inches.	Safe for a column of water in feet.	Weight of length of 10ft.
in.	in	ft.	lb.
5	2½	10	36
5	2½	25	70
5	2½	45	84
5	2½	70	96
5	2½	100	112
5	2½	150	130
6	3	10	42
6	3	20	60
6	3	35	80
6	3	60	100
6	3	90	112
6	3	110	120
6	3	140	130
6	3	160	140
7	3½	10	56
7	3½	45	90
7	3½	80	112
7	3½	100	120
7	3½	130	130
7	3½	150	150
7	3½	180	166
7	3½	200	184
8	4	10	56
8	4	25	70
8	4	40	80
8	4	70	112
8	4	100	140
8	4	170	160
8	4	190	170
8	4	230	200
10	5	70	170
10	5	110	200
10	5	150	234
10	5	200	254
10	5	300	280
12	6	250	300
12	6	300	316
12	6	350	333

Pressure on Close Tanks.

The pressure on the sides of a boiler or hot water close tank, is in this manner calculated, and the strength of such tanks must be in strict accordance with the statical water in the vent or air pipe, which is too often by the plumber overlooked.

Fixing Lift and Force Pumps.

Having explained the pump table and the weight or substance of lead pipe, for wells of different depths, &c. we will proceed with the fixing of the lead lift and force-pump, Fig. 829.

First fix the stage C, which ma[illegible] two pieces of oak quartering, say 4in. b[illegible]

shown at Fig. 832 (the latter material is much the best for durability) then fix the suction-pipe on the barrel, and prepare the bottom for the flange joint D. Pass it through the lead flange, to rest upon the top of the stage, which if of iron should have two pieces of brown paper or paste board to keep the lead flange off the cold iron during the soldering. After this take the board away, and allow the lead

FIG. 832.

flange to rest upon the stage; then fix the second stage H, which should not exceed 9ft. 6in., next turn another flange joint over the lead collar, and make the joint M, and so on to the top. When on the last stage, as at I, a branch joint for the rising main must be wiped on to the barrel. Take care that spurs of solder do not come through the barrel, so as to prevent the free passing of the bucket. Now open

FIG. 833.

the end of the barrel at R, and taft the top over the lead flange, which should be $\frac{3}{8}$in. to $\frac{1}{2}$in. thick, and 8in. larger than the barrel, viz., 4in. on each side for nailing, &c. Next take the stuffing-box and flange, Fig. 834, and unscrew the top of the flange Z, and tin the edge of it; after which fix it quite central and *truly upright* with the barrel, and solder it with the top of the pump barrel to the flange

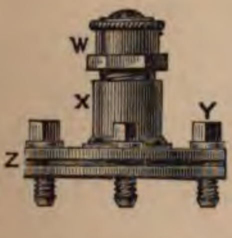


FIG. 834.

FIG. 835.

as shown at L R, Fig. 829, or, instead of this stuffing-box, shown in Fig. 829, another kind known as the Bath stuffing-box, as shown at Fig. 835, may be used. This top has a ...w cut at T, Fig. 835, instead of the flange screws known ...n screws, see F... Fig. 794. Of course, as may be ... 835, a s... ...h is used instead of a screw

driver. The next thing required to be done is to fix the sucker box E, Fig. 829, and get the bucket fixed on to the pump pole. On the top of the pump pole is fixed a *hard drawn* copper rod, L, see Fig. 836, which works through

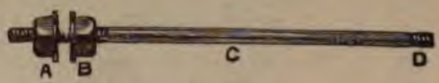


FIG. 836.

the stuffing-box. This rod is generally sold with the stuffing-box properly screwed, and with adjustable connection nuts A B, to hold the bow connection, as shown at L K, Fig. 829, and also at K, Fig. 837. You must fit the pole on the pump-rod with screwed, forked irons, as you did at N, also at E, Fig. 798 and 826. Of course the pump-rod, Fig. 829, may be worked with a lever handle on

FIG. 837.

plank, as shown at Figs. 889, 890, &c., or with the compensating wheel 3, which rotates on a plank, as shown in Fig. 829, or otherwise. The top of the bow connection works through a guide, V, which keeps it perpendicular, and prevents the copper rod getting bent; this will be further explained in Pump Rigging and Fixing. It may be noticed at Q, Fig. 829, that this wheel has a balance-weight, which may be made exactly to half or to wholly balance the column of water, pump-rods, &c., and by the use of such an arrangement it will be plain that a regular swinging, pumping motion may be obtained. At I N may be seen an air-chamber, and it is rather important that this pump should have one fixed either at G, or I. When the place is selected as it should be, at G, and the chamber is as per dotted lines, it will be seen that this barrel passes through the air-vessel, and when such is the case 1in. holes or slots *large enough* should be bored all round the barrel as shown at N, not more than 3in. up, or above the bottom of the air-vessel, and take care that the rough edges of the holes caused by the boring are taken off the inside of the barrel, otherwise they will prevent the passing of the bucket. It is a good plan to bulge out the barrel here a little which will allow the bucket to pass the holes without rubbing against them. Of course the top and bottom of the air-chamber must be properly soldered to the pipe. This air-chamber is drawn large in proportion, because the barrel of the pump is made to pass through it, and which of course greatly reduces its capacity, that is to say, so far as the useful effect of the air-space is concerned.

FIG. 838.

Hanging Pumps.

Suppose it is required to fix a deep well pump, say 50ft. deep, without entering the well, and where a 'suction pipe' would not act, this is done as follows—see Fig. 838. The barrel A is, by the aid of iron pipes, let down to rest upon a good solid foundation in the bottom of the well; but if this cannot be obtained, it may be swung. Of course, it is then supported by suitable stays, &c., at the top, and the top part A made good. When such pumps are used, take care that the pipe (iron, copper, or brass) used is strong, and as large as is necessary for the support of the lower parts, and for the free working of the pump-rods, which should not exceed $\frac{3}{4}$in. A 2in. wrought-iron steam barrel, or solid-drawn thick brass tube, will do for the piping. You can now select a barrel suitable for the work, for which see table, and for the size of pipes see Suction and Rising Main Pipes. The barrel should be double the diameter of the suction pipe, and work as follows. Let the area of the rising main pipe, B, Fig. 838, after deducting the area of the pump rods, be $1\frac{1}{4}$in. In the suction pipe table, we find that a $1\frac{1}{4}$in. will suit a 3in. pump-barrel, D, Fig. 838, should be this size; and notice that a 3in. barrel is the correct sized pump for a 50ft. well. Sometimes the rising main is the same size as the barrel all the way up; then the bucket and clack can be withdrawn without pulling up the barrel.

The hanging pumps are made to a variety of patterns by Messrs. Warner.

Shallow Well Wheel Pump, Frame Pump, Friction Wheels and Ball Bearings.

This, Fig. 839, is one which is sometimes used when the well is shallow, and may be used with advantage for placing within a building or outhouse, the suction running horizontally to the well; by adopting this frame where practicable, a man can work in comfort, and the repairs can be done without opening the well. The Frame Pump works much easier than a Wheel Pump fixed upon a plank with only one shaft bearing, simply because in the latter there is a kind of twist on the brasses, pin, or hole, of the wheel (for this, examine Fig. 829). Here we see the wheel is working truly upon a pin, but the pump rod tends to pull the whole towards the front, and the bearing is upon the top end of the pin, and on the underside at the back, to say nothing of tending always to pull against the front part, or head of the pin. The same applies to the wheel in Fig. 858, and also Fig. 868, but not nearly so much in *Fig. 870*. Notice the difference in Fig. 871; here the shaft takes two bearings, but has the weight of the rods dangling on its one end, whilst that in Fig. 855 has the

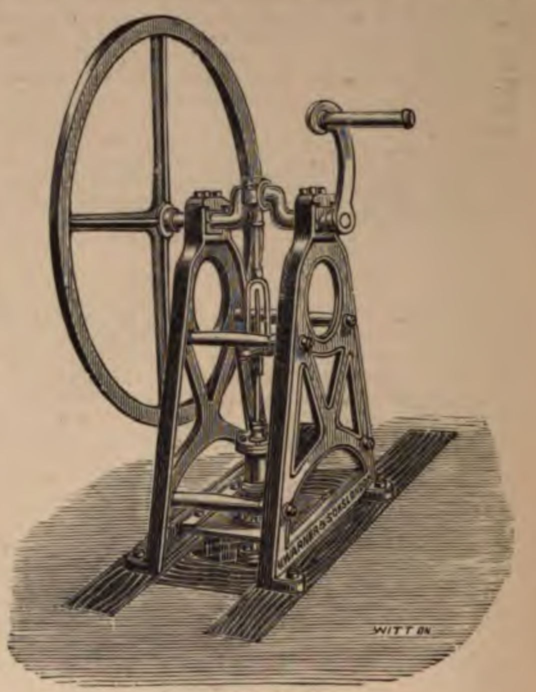


FIG. 839.

weight equally divided upon the two bearings. All these apparently insignificant-looking little points in time become a big lot when a man has to work away at this grinding job for a day or so together, and everything to make the pump go easy should be studied. I have fitted wheel pumps with axles to run between frictional wheels and rollers; I have also fitted them to run between ball bearings with good results.

Jack or Plunge Pumps.

It frequently happens in the country that the intelligent working plumber is called upon to arrange and fix some simple and *cheap* hand-made pump that will throw water out of a cellar, quarry cutting, over and about a farm-yard or garden, to a closet cistern, &c. The following is one of the best and most simple that he can make up, see Fig. 840. This is a piece of, say 4in. pump barrel, tapered at G to receive the sucker; into this, about 2in. above the sucker branch a piece of 2in. lead pipe, as at J, then make the air-chamber in size to ten times the quantity of water to be pumped at each stroke; say it was a 10in. stroke, and a 4in. pump, then the size for the air-chamber should be 25in. long by 8in. diameter. A piece of 6in. pump barrel of suitable length will answer this purpose. Over the end of the 2in. pipe Z, put a stout lead disc, W, and taft over the end of the 2in. pipe to receive a short 2in. spindle valve, as shown at I, Fig. 840, and wipe the lot [illegible] then w the cover O on to the disc, and p[illegible] now wipe on the suction pipe I, and [illegible]

the sucker F. Prepare the bucket or plunger B, which is nothing more than a solid round block ½in. less than the barrel, having a pump rod which should be jointed near the bucket as at A and S, and with two bucket leathers A and D, fixed on the top and round the bottom, or these buckets may be as shown, two ordinary solid cup leathers shown at G, Fig. 799, and butted together as at A, D, Fig. 840. The action is as follows: Upon the descent of the piston the air or water between D and E becomes pressed upon, and it is forced up the pipe J, K, when the valve K opens, but upon the down stroke of the handle being taken the valve K closes to prevent the water running back, and which dispenses with the stuffing box to the lift pump, Fig. 800. Here is a place where the valve K must be used.

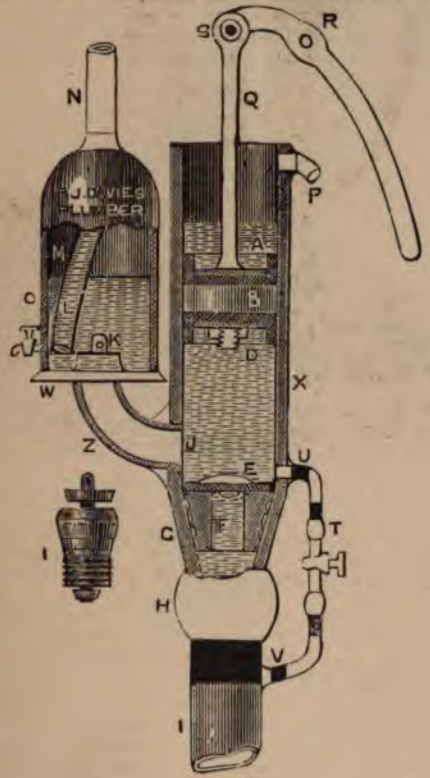


Fig. 840.

Now when the down stroke of the handle is taken the piston A rises, and tends to produce a partial vacuum, and the external atmosphere forces water up the suction pipe, and through the valve F into the barrel, when E again closes. Fix this pump as you did the jack-pump, Figs. 804, 806, and 810, or as best you can. Of course, in this Fig. 840, a wheel may be used. You will find that by continual pumping, the water is apt to fill up the barrel and overflow; it is therefore necessary to fix an overflow pipe as at P, and carry the same outside the woodwork. If the pump is so placed that it will be affected by the frost in winter, fix a cock and piping as at T, which answers two purposes, viz., for the barrel and suction pipe, and is much better than two cocks; the water in barrel always charging the cock which prevents it drawing air by the plug. There should also be the cock O, the latter should always be fixed ...re to get water, and also to empty the pipes and air ... At times put a joint in the pump rod at A like Fig

Lift-Pump.

This pump (Fig. 841) is the well known lift-pump, and is generally fixed against the wall near sculleries, sinks, and in wash houses, &c., and is used as a suction pump for the scullery, and other purposes, also as a pump to lift water into cisterns for water-closets, baths, hot-water cisterns, &c. The action of this pump is exactly the same as that at Fig. 800, the only difference being that in Fig. 841, the piston rod is made to work with guide and rod, and sling instead of a rocking standard, and that this


Fig. 841.

barrel of the lift pump is of brass or gunmetal, fixed with nuts and bolts to a plank, and the plank fixed by long bolts and nuts to the wall. As this pump is in general use, and as by a glance at the diagram it may be seen how to fix it, I shall, after what I have said on pump-work, only have to point out those parts which require periodical repairing, and explain the manner of doing it. If you will now examine Fig. 842 you may notice that this pump is fixed as shown, with an air-chamber (see Air-chamber), though this is not always the case, but the rising main is at times wiped on to the top of the chamber-box, M. Always let the rising main pipe be bent with an easy bend, as shown, it is better to get the flange off for repairing the valve at M. When the air-chamber is not fixed you will find the main often bursting, and so will require constant attention for repairs; secondly, the air-chamber not being fixed, you will very likely find the copper pump-rod to get broken. Thirdly, the heavy thumps of back water upon the valves at M B will cause the valve leathers to wear away quicker than when the air-chamber is fixed. Fourthly, the pumping work will be much harder. Fifthly, there will often be an unpleasant rattling noise within the rising main, especially if of a long horizontal length.

Repairing Lift-Pumps.

To repair the leathers, unscrew the screws on the top flange, lift the flange and rising main, and re-leather as before directed. Here, when lifting the rising main, you will find the benefit of this pipe being bent in the manner before described. Next is the sucker valve Q; this is often only 10in. or 12in. from the floor; it is no use to unscrew this, thinking to pull the pipe and flange on one side for re-leathering. No, you must go to work differently. Take out the sling pin G, at D in rod, and it may often be necessary to unscrew the guide spindle or rod. Now, if you think proper, unscrew the top, and carefully take out the bucket, but do not bend or otherwise injure the copper piston rod. Next take the barrel off the plank, and away from the flange Q; you may now re-leather and refix as before. Notice, never fix a lift-pump that does not allow of being taken off the plank *from the front;* where they are screwed on from behind they cannot be taken off should the sucker be as just described, unless the plank and pump can be removed bodily. After repairing the valves always fill the barrel before putting in the bucket: you cannot otherwise get water into the barrel to prime, fetch, or suck the water from the well.

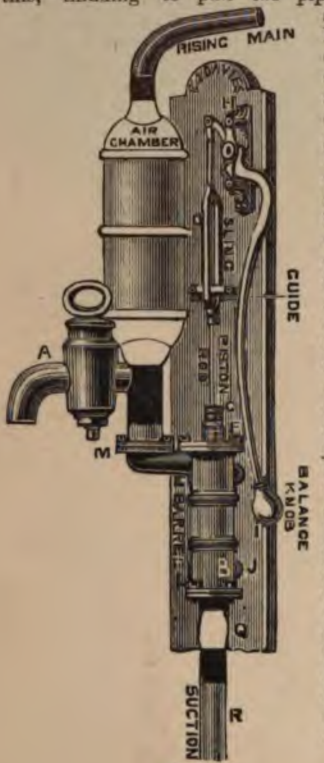


FIG. 842.

Pump Screw Dog Wrench.

It often happens that a sink or something is fixed against

FIG. 843.

the pump barrel, and in such a position that you cannot get the screwdriver to turn out the pump-screws, F, L, for repairs. When such is the case, you will require a pump screw dog-wrench; this tool is nothing more than two pieces of ¼in. steel plates A, B, C, D and E, F, G, H, Fig. 843, fixed or welded on to a flat bar, E, as shown. By the fixing of the plates as shown, the slots in the heads of the screws can be got at and the screw unturned. Of course if the plates, F, G, are at an angle of say 22½°, and the plate, D B, at an angle of 45°, or at right angles, it will be plain that a screw may be turned within a very narrow or limited space, and where a screw wrench or screw-driver would be of no use whatever. For easy repairing pumps see A, Fig. 860; such openings are made on pumps as at Fig. 824, &c.

Cottage, Iron, or Garden Lift Pump, with Rocking or Vibrating Standard.

This pump is illustrated at Fig. 844. It is cheap, but it is not fit for hard work, nor will it be found lasting (you will also find the cup leathers wear out quickly), although in certain situations it will be found very handy. It is made up as follows: M is the plank, A an iron bracket whereon is seen to rest the pump and suction, or lower flange, and upon which is formed the sucker valve seating, over which fits the sucker valve leather; and at A is fitted

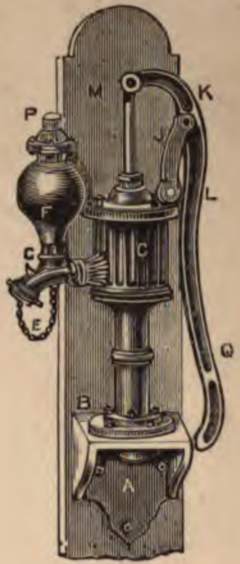


FIG. 844.

the suction pipe, at times connected with a nut and lining, or union. The pump rod L Q is worked on a vibrating standard J; and the piston rod is also made to work through a stuffing-box. On the nozzle, G, is fixed an air-chamber, F, for use when the pump is to be used as a lift pump; and in such cases the cap, E, is used as a stop cap to prevent water running out at the nozzle.

Of course, the rising main pipes or hose may be screwed on to the end of the nozzle instead of being taken off the top of the air-chamber at P, or in many other ways. The internal part of these barrels, is at times lined with a brass or copper tube, which prevents the cup leather wearing out so quickly as will be found to be the case when rubbing against the iron barrel. Such tube is cemented with hot resin and suet as if cementing cocks into sockets or bosses.

Jack-Pumps with Guides and Slings.

It sometimes happens that a jack-pump having very much work is fitted with guides and sling. When such is the case, any of the former rods and slings will [illegible]: but the one I prefer for lead pump is that showr
889, and which is as simple as any; but

perhaps that shown at Fig. 845 is as good as any. The sling, J, and handle, H, with the top can be turned to any

FIG. 845.

position, and, as may be seen, is attached to the pump-rod below the rod-guide, and needs no further description.

Beer Engines.

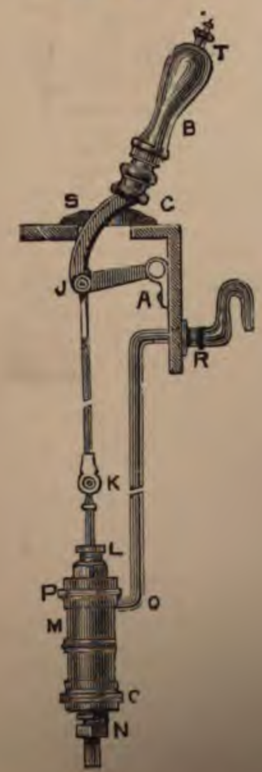


FIG. 846.

Whilst we are upon the subject of Rocking Standards, etc., for producing a partial parallel motion to the piston or pump rods, I will introduce another kind much used in the beer engine work, and which is illustrated at A J, Fig. 846; and as every country plumber has more or less to do with the repairs and fixing of these pumps, the more is the reason why I now introduce it to his notice. It is the first step towards the explanation of the vibrating lever, for which see Fig. 869.

Fig. 846 is the beer-engine pump, to which every plumber should give his particular attention, not necessarily for its contents but for fixing and repairs. There is no kind of pump more delicate than the beer-engine, and none gets less attention from the plumber. This pump-rod, as may be seen, works on a quadrant, A J C. The lever being hinged at A causes the rod to pull up nearly straight, owing to the lever part, A, J, being made to work at right angles with the pump rod when at half stroke. It is coupled by a joint at K, it here further reduces the liability of the rod being bent, unless the pump-bucket gets too high, and thereby sticks in the top of the barrel, where the beer has furred round the inside, then the chances are that the bucket will stick up, and if main force is used to push the handle and rods back, they bend, and require the attention of the plumber to put in new rods.

There are other kinds of rocking or vibrating standards, as can be seen on the right hand side of Fig. 847. There are also standards composed of a spring, which vibrate without joint.

Plumber's Force-Pump.

For this, and for the sake of simplicity, I will refer you to a diagram of the well-known plumber's force-pump, which every plumber has had to do with, and for which (see Fig. 847). The diagram on the right hand side is that

in general ... v under-
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K

Pole and Plunger-Pump.

The pole and plunger-pumps are generally used where a very high pressure is required, such as boiler feeds, &c. Their construction differs from any of the former pumps, as may be seen by reference to the Fig. 848. G is the shell of the pump. All the pumps before explained have had a barrel wherein was made to work a cup or bucket-leather; but in this pump we substitute J, which is simply a truly turned pole or plunger, which saves boring of the pump-barrel, and which works through a stuffing box, shown in Figs. 847 and 849, or as here shown, through the cup-leather Q, fixed between flanges K. It may be noticed that the sides of the poles answer to the cup-leather precis ly the same as the sides of the barrel to the pump-bucket. I may mention that this kind of cup-leather was used in the old pumps at York-buildings water-works, date

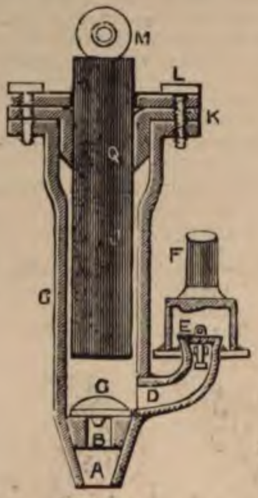


FIG. 848.

about 1740, and is in principle exactly the same as those used by Bramah in the hydraulic press.

After what I have said upon the principles of pump-work, this plunger pump will be readily understood. Its action is as follows: On raising the plunger J, it closes the outlet valve E, and opens the suction-valve C, at the same time draws water through A, and into the shell C. On the descent of the plunger, the valve C closes, and the water ascends the pipe D; valve E is forced open, and the liquid forced from the shell into the rising main, and so on alternately. For very high pressure these valves are ground in metal feathered or spindle valves, as illustrated at E F, Fig. 849. More will be said on the plunger-pump when we come to presses.

Plunger and Feed-Pumps.

For this kind of pump refer to Fig. 849. It is the one generally selected for feeding boilers, and may be used for many other purposes, such as in soda-water works, machinery, hydraulic presses, &c. These valves are of the feather-guide gun-metal class, and of course are ground in. The bottom flange K is screwed on to a plank, and the pipes taken where required. The suction should never exceed 6 ft. or 10 ft. in length, 3 ft. will be quite long enough if worked very rapidly. On reference to this pump it will be seen that the plunger or pole works through a stuffing-box Q, having leather washers, and hemp or other packing, which is screwed down with the gland D, and

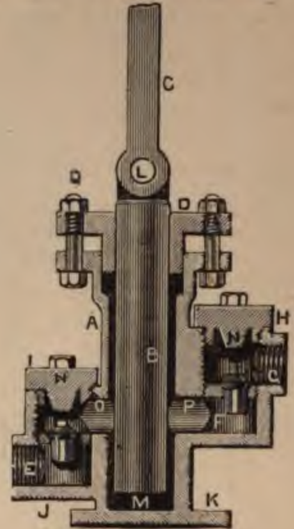


FIG. 849.

which answers instead of a cup-leather, as in Fig. 848. Now let us closely examine the cup-leather and the stuffing box with a view to finding out which is the better.

Pump Stuffing Box Packing.

In the stuffing-box the gland D must be kept tight down upon the packing. This packing is nothing more nor less than a quantity of greased hemp, which is put into the box as follows: First for cold water work, cut two good leather washers, the diameter of the box, and to fit the plunger tightly; now get some good straight hemp or spunyarn, sufficient in quantity to fill the box, pull the ends to a taper, and dip it into some hot tallow, *not boiling*, take it out and let all the surplus fat run off, then pull the gland D and next the plunger, about three parts of the way up; perhaps the old packing will come with it, if not, with a suitable bent, sharp, but round pointed tool, pick it out, after which take the prepared hemp, which is by this time cold and the fat set. Now begin, say, about 6in. from the end of the hemp, to wrap it round the plunger. Bring or wrap the short end of the hemp up the plunger, and in such a manner that the end cannot work through the leather washer and into the shell of the pump. Now, with a ½in. or other suitable blunt-pointed, gauge-shaped tool, push the hemp down into the box, and wrap the remainder round the plunger, put on the leather washer, which should fit the plunger *quite tight*, then put on the gland, and screw it down, *but not too tight*, or you will most likely squeeze all the fat out of your hemp. Screw the gland down only sufficient to make the packing water-tight. If screwed too tight, the friction will be in proportion all the greater. It is the friction which is so much against this class of pump. Now, if you again refer to Fig. 848, you will there see that the friction on the cup-leather is only in proportion to the pressure on the pump. It closes against the plunger by the aid of the fluid pressure, and if there is no pressure within the shell of the pump, there will be no pressing of the cup-leather to the sides of the plunger. This c[illegible] be the fact with the stuffing box for or[illegible]

tightly screwed down, it remains so until worn away, which in some cases it does quickly. The cup-leather will last at least three or four lots of packing, and the pump will work much easier. You will perhaps ask, Why use the stuffing-box at all? The answer is that the leather will not always suit your class of work; for instance, it will not suit hot water, because by the heat it soon gets perished, but in cold water it will last for years without attention, viz., for ordinary pumps.

Suctionless Pumps and Coal Pit Pumps.

After what we have seen of stuffing or packing-boxes, and cup-leathers answering their purpose, it may be asked if we cannot dispense with them altogether. In some instances we can. See the pumps, Figs. 838 and 850. These are a class of pumps wherein no packing-box or suction-pipe is required, and although not much known to the modern plumber, the latter especially, were well known four or five hundred years ago, and were used at the celebrated water-works at

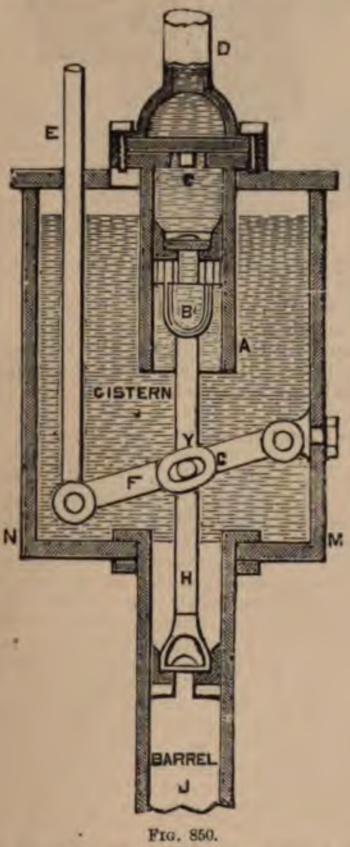


FIG. 850.

Marli, and at Pont Neuf, a French water-works of about the same magnitude, class, and date, as our original water-works erected at London Bridge. Place a piece of paper over the line M, N, to cover the lower barrel. The pump-barrel, A, is then to be seen fixed in a cistern; the bucket is submerged, and the rod working from below is actuated [illegible] the vibrating-lever, F, G, and the pump-[illegible]l be seen that if the valve, C, be also submerged, that on pulling down the bucket its clack will open, and that the water from the valve C to the bucket, being below the level of the water in the cistern, is not required to be upheld by the external atmospheric pressure, and, therefore, there is not that which is known in pump-work as a suction-pipe. The advantage of using this kind of pump, is that light pipes may be used for pumps miles deep, which will readily be seen from what follows. (Take the paper off the line M. N.) Suppose the rising main to be 1,000ft. long, you will according to the half pound per square inch to the vertical foot, have a pressure of 500lb. to the square inch on the bottom pipe. Now it will be plain that if you have ten such cisterns, and ten such pipes as that in the illustration, and that if these ten cisterns are supplied from one bottom cistern, the pressure on each pipe will only be one-tenth of the 1,000ft., and so on, according as you fix the cisterns. Of course to gain this object, pumps of any other class may be used, such as ten lift-pumps, or jack and plunger, &c. At J, Fig. 850, may be seen a suction and lift-pump, which will save at least one cistern, because you may have 20ft. of suction and, say, 50ft. to 80ft. of rising-main. Such pumps are much used in mines, &c.

Continuous Action Lift and Plunger Pump.

This pump is a kind of double-acting, and is designed for the purpose of throwing a more continuous stream than can be thrown by any of the former ones. The action of this pump will be readily understood by reference to Fig. 851. G is the barrel in which the bucket, F, as also the

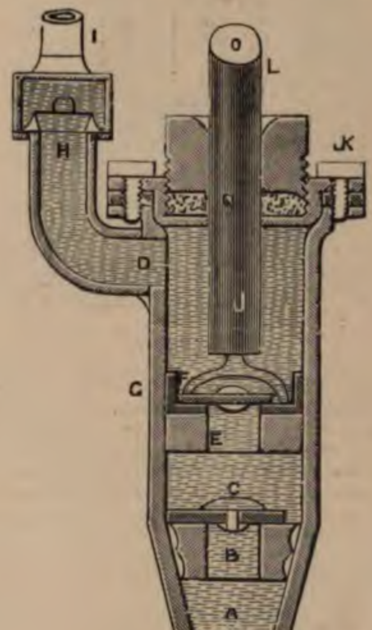


FIG. 851.

plunger, J, is made to work. Take notice, and you will see that the water is made to rise up the main pipe at the hand and backstroke of the pump as follows. Suppose the plunger to be half the area of the pump-bucket, it follows

that by raising the bucket, the water, as is usual, follows, and that the water in front is urged orward up the barrel, and into the rising-main; but at the same time, the plunger is going out of the barrel, and consequently less water rises up the rising-main, thereby making room for water to the extent of the exact size of the plunger only. Now give a back stroke, and down goes the plunger within the barrel, and again displaces water up into the rising-main, in exact proportion to the size or bulk of the plunger, so that water is made to pass through the rising-main at both hand and back stroke. Of course, in Fig. 851, a cup leather, as at Q, Fig. 848, may be used instead of the stuffing-box.

Double-Acting Continuous Pump.

This pump is illustrated at Figs. 852 and 853, and differs from all the foregoing pumps, though in principle it is much about the same as the jack and plunge pump, Fig. 840.

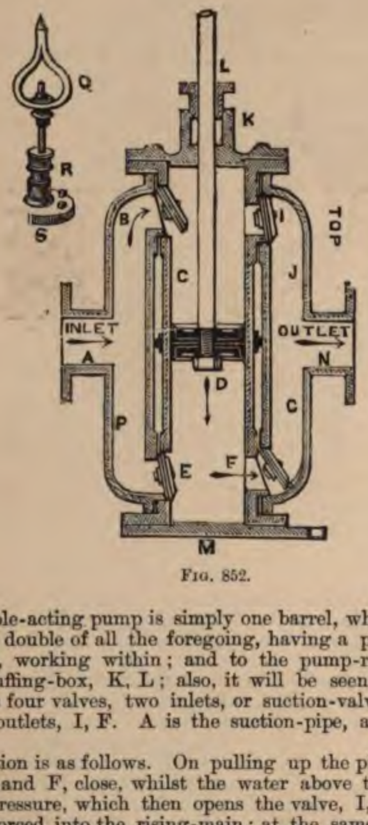


FIG. 852.

This double-acting pump is simply one barrel, whose work is exactly double of all the foregoing, having a plunger or piston, D, working within; and to the pump-rod, C, we have a stuffing-box, K, L; also, it will be seen that the pump has four valves, two inlets, or suction-valves, B, E, and two outlets, I, F. A is the suction-pipe, and N the outlet.

The action is as follows. On pulling up the piston, the valves, B and F, close, whilst the water above the piston receives pressure, which then opens the valve, I, and the water is forced into the rising-main; at the same time E, by reason of the suction, also opens at the same time as I, and allows fresh water to rise into the barrel of the pump. Now give the back stroke to the pump-plunger, and the valves, E I, will close, and B F will open simultaneously, and so on alternately. Notice, I have here again referred you to hand and back stroke, as this pump is often fixed so that the bucket-rod will reciprocate in a horizontal, instead of a perpendicular direction, the suction, A, being fixed direct over the pipe leading nto the well, and the outlet perpendicular with the rising-main. When fixing these pumps horizontally fix them so that the outlet will be at TOP (Fig. 852) so that the valves will shut when fixed in the horizontal position. Q R (Fig. 852) is the bow for connecting the pump-rod to the working lever, &c. Fig. 853 is an

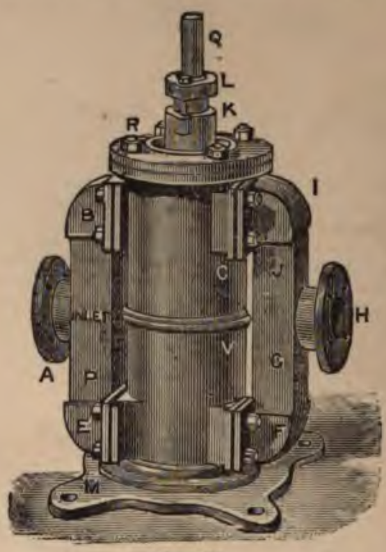


FIG. 853.

elevation of this pump, and which well illustrates the flanges at B E F, &c., and which takes apart for releathering the valves. This pump is largely used in fire engines and ship-pumps. Also for blowing purposes. The action of this pump is the same as that in the double-action waste preventer. [Figs. 641 and 642.] As the Section Fig. 852 is now fixed it is a continuous primed pump.

Fire Engine and Ship-Pumps—Quadruple Action.

Fig. 854 is a sectional elevation of a quadruple action ship-pump, or one capable of doing the work of four barrels—just double that of Fig. 852. It will be seen that in the pump there are two barrels, A, K, one fixed above the other, and in such a manner that only one pump-rod is required to work the two pistons, plungers, or double buckets. On the opposite side of the barrel is fixed two longitudinal external chambers, or water channels, L, H (see B, Fig. 855) and having inlet and outlet-valves I, O, M, N, which, in reality, are nothing more than those at B, E, F, I, Fig. 852; but in the diagram 854 are the two distinct barrels, working into and only lifting one double set of valves, which must be large to compensate for the extra friction. There are two stuffing-boxes to overcome, and the dead points come round twice where they should only come once, which is on account of the very short stroke (but which, of course, might be altered to a longer one) between U and T.

The head, V, forms an air-chamber, which may be extended to any size though shown here small. The stuffing-boxes require to be kept screwed up very tight, which means more friction. With this arrangement too much labour is required to work the pump. Work the spindle stuffing-boxes a little loose. The action of this pump is as follows:—Turn the wheel to cause the bucket to ascend; this closes the valves I and N, after which the outlet valve M opens to allow the water to get into the head air-chamber

or main pipe; but at the same moment that M opens, so also does the suction-valve O, to allow fresh water to enter the pump. Give a back stroke, and O M will close and I N open, and so on. Of course, this pump can be worked by steam or other power, as in steam fire engines, &c.

Fig. 855 is an elevation of the ship-pump Fig. 854, which illustrates the two handles, and also the hose and

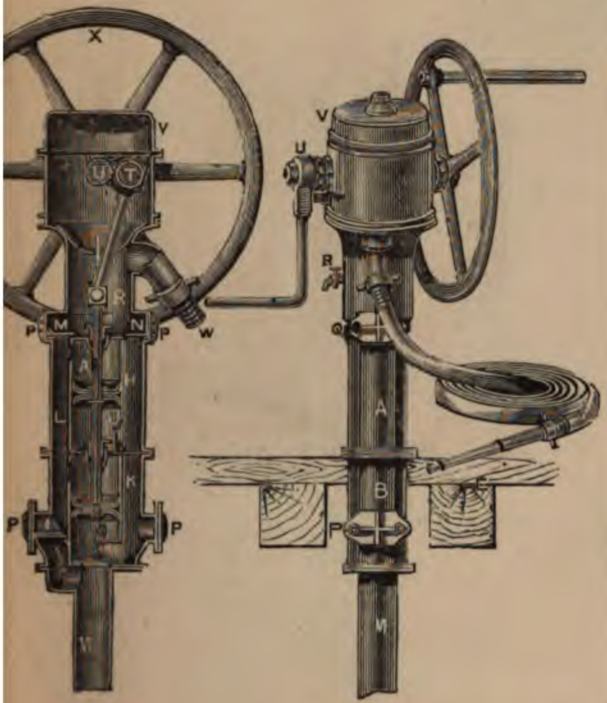


FIG. 854. FIG. 855.

branch-pipe E; it shows the spindle stuffing-box, the valve doors P Q, and the trial-cock R; and it also shows one method of fixing the pump between two stays made with quartering, &c. Return for a moment to Fig. 854: suppose the pump to be out of order, and that *no* water can be obtained. What should be first done under such circumstances? The answer is, Examine the sucker-valves O I, for *one* of them is almost certain to be out of order, which may also render the other useless, unless the outlet valves and stuffing-boxes are perfectly tight. This valve must then be either cleaned out or releathered. But suppose you have plenty of water in the barrels, and that the pump throws at the hand or back stroke only. What is then best to be done? The answer is, If it throws *only* at the hand stroke, examine the outlet-valve on the back stroke, for it is sure to be out of order. It allows the water to "jig"—that is, as the plunger works up and down in the barrel, so will the same water keep pace with the plunger; and why? Simply because the outlet-valve allows the free passing of the water backwards and forwards, and so does not answer its purpose, viz., to stop the water running back into the barrel. It is possible, but not very probable, that both outlet-valves may be out of order at one time. Should such, however, be the case, the effect will be that there cannot be any water pumped, because the pistons will throw the water back, to supply the reverse stroke of the plunger, and you will be apt to think that one of the sucker-valves is out of order. Now, to determine whether it be the top valves or not, open the small trial-cock R, Fig. 855. If water flows out, the bottom valves are sound, and the two top, or outlet valves out of order. Whatever refers to the valve action in this pump also refers to the double-action pump, Fig. 852.

Diaphragm Pumps.

This kind of pump is illustrated at Fig. 856. A is the chamber, with flanges to hold the india-rubber diaphragm K, and the suction-valve B, with the outlet-valve E. The action is as follows:—Fill up the pump or chamber A with water; also the pipe E up to the valve F, and work the handle; this will soon produce the necessary vacuum in the suction-pipe.

This pump may be made to work without the valve E by forming a valve in the diaphragm that will open outwards.

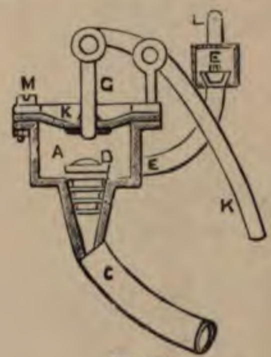


FIG. 856.

FIG. 857.

Bellows Pumps.

These are very old kind of pumps and are shown at H I J, Fig. 857. All that is necessary is an inlet and an outlet-valve, as in the lead-burning bellows, Fig. 66. The pipes should be fixed upon the bottom board, and the top may be worked by any mechanical contrivance. The closet regulator is of this class.

Deep Well Pump-Work and Rigging.

We have now seen nearly all the various kinds of pumps which the ordinary plumber has to do with. I will, therefore, proceed with our deep-well work, such as is illustrated at Fig. 858, and explain many of the different methods of rigging them up, suitable for the various kinds of pump-work which the country plumber has to execute, according to his district, &c. First, let us examine the well wherein the pump has to be fixed, as at Fig. 858. This is a well of, say, 20ft. to the stage B, upon which rests the barrel A; N F, the rising main; D is the suction pipe which is, say, 8ft. long; K is the roller guide; H L the pump rods; M the plank; P the guide, which in some cases is not required; there is also a WARNING-PIPE on the left. Here the whole is exposed to view, and is very simple to understand, and is one of the simplest methods of deep-well pump fixing, and here two views are shown of fixing the pump and rising main, left and right handed.

I shall now introduce to your notice another method of work, and a little improvement upon the Fig. 858, just

explained. For this refer to Fig. 859. Here the pump is of the same class, pump rods and all are the same, except the rising main. In this we have the pipe supported on the stage with a flange joint, and also an air chamber on the rising main at V, we have also an emptying cock as shown at X. These, though they may appear but slight improvements, are of great utility, which will be explained as we proceed. But I think I hear you say, What do we want with all this paraphernalia for a well only 20ft. deep, as a common jack-pump would do the work? Quite true,

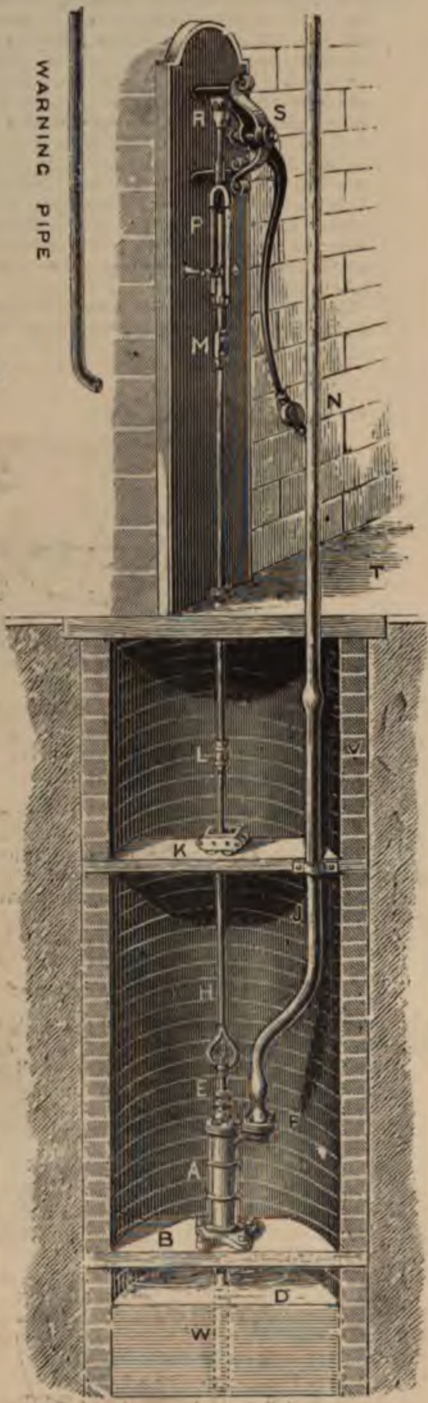


Fig. 858.

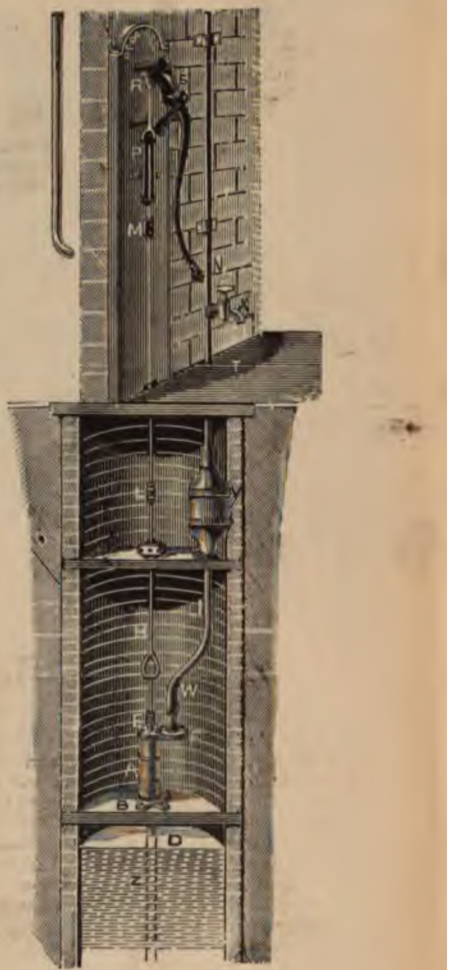


Fig. 859.

but notice, in the summer months the water in the well subsides, or, after you have pumped, say, for half an hour, the water is lowered, say, 4ft. or 5ft., so that a jack-pump would be useless for such work, and therefore another kind must be used. The best kind for your purpose will be the lift-pump, as shown at Figs. 860, 861, 862, and 863. Carefully examine these pump-barrels and select that which you may think most suitable to your price, and for the job. Fig. 862 is simply the same kind of pump-barrel as that fixed upon the plank at Fig. 841, the difference being that this latter has lugs on the side of the barrel for securing to

Lift Pump Barrels. (Also see Fig. 892A.)

Fig. 860.

Fig. 861

Fig. 862.

Fig. 863.

the plank, which, if used for deep-well work, must be securely fixed with coach screws, &c., to the sides of the stages, as on the front of the stages B and A, Fig. 864, whilst Fig. 862 has the lugs on the bottom, as shown at B, Fig. 861. In this latter figure the pump has to be taken to pieces to examine or repair the valves; but the valves in Fig. 860 may be examined or repaired from the doors A or D. In all other respects these pumps are exactly the same. ·r my part, I should use Fig. 860.

· will now proceed with the fixing. The first thing ... what will be the actual height that the water has to be lifted? The well, taking the subsiding of the water into consideration, is, say, 30ft. deep, but it does not rest here. The water has to be lifted to a cistern, say, 30ft. above the ground level, thus making in all 60ft. I may here remark that all pumps should be rotary as at the left, Fig. 858, if they are to be continuously worked, especially for deep wells. The pump is to be worked by a man with an ordinary pump lever, as shown at R S, Figs. 858 and 859, whose leverage is 6 to 1. The question now is, what sized barrel will be proper for you to select so that he may work easily and continuously? Turn to the pump table, and consult the column of feet at 60; here you will find that in the next column the size of the barrel suitable for a lift of 60ft., to be worked by one man, will be 3in. diameter; but notice that this is the very outside of the scale, and requires 30lb. on the lever to work the pump, not taking friction into consideration, and under the circumstance that this sized pump is too large for even a strong man; it will be quite as well, therefore, to consult the pump table and to select the next size smaller, namely, 2½in. barrel. On a 2½in. barrel a column of water 60ft. in height (see WATER PRESSURE TABLE) will exert a pressure on the bucket of

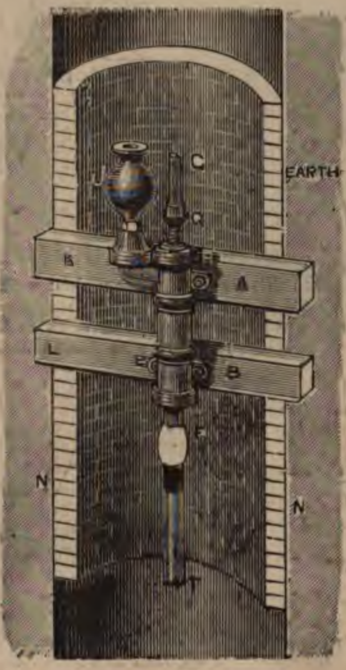


Fig. 864.

127lb., or 56lb. less than that on the 3in. bucket. Now divide the 127 by the leverage of 6 to 1, and you find we only have to exert a pressure of 21lb. upon the handle, when the pump is said to work light on the hand.

After what I have said, you may select from the table a barrel suitable for a well of any depth. But as we proceed we shall have to use vibrating and other compound leverage, and which will have to be worked and taken into consideration with the pump table. The next thing to consider is the size and substance of the lead pipe, suitable for the pump, and also for the pressure of 60ft. or, say, 30lb.

to the square inch. (See Table and Length of Working Strength of Lead Pipes.) Here we have a 2½in. pump barrel, and half the diameter will be the size for the pipes; therefore, a 1¼in. pipe is the size for the suction and rising main. Now turn to the table and look for 2½in. pump, and in the second column will be found 1¼in. pipe; then in the third column run your eye down to 60, which means 60ft. column of water; on the same line in the fourth column will be seen the figure 42, which means that the substance of the pipe should be 42lb. to the 12ft. in length, known in the trade as a length of No. Forty-twos.

Now that we have the size of barrel, and also the weight or substance of lead pipe, we may prepare to fix the barrel. First settle as to the spot for the stage, which, in this case, is composed of two pieces of good oak, made the proper length to go through the brickwork, and, say, 5in. or 6in. thick by 9in. wide. First get the back stage A, Fig. 865, in, next the front B, or if you choose, only fix one piece of timber, with the suction-pipe hole E bored through the centre.

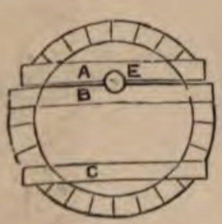


Fig. 865.

Next put in the side stage C, after which, with some good oak boards or pieces of oak plank, floor over the whole, and proceed to fix your other stages above, as at K, Fig. 858. The roller-guide K, which is also shown at Fig. 866, is fixed when the rods are, but *notice* that you fix the stage K, Fig. 858, so that the rods will play through the centre of the hole, which *must be plumb* over the suction-pipe hole, and so on all up the well. If iron stages are to be used, such as those shown at Figs. 832 and 833, especially the latter shoes, as shown at A B E, Fig. 833, must be cemented into the brickwork, and the ends of the stages *bolted* down upon the shoes. Sometimes it will be best to fix your stage, so that the pipe and rods will work at the back and front of the stage, as shown at Fig. 866. With such stages, sometimes, you may have to use side rollers, as shown at E, F, G, Fig. 866. The Fig. on the right shows round faced rollers, whilst that on the left shows hollow rollers. These are called wood stage rollers, but are often used for the iron stages, and are bolted on the side, as shown at E F, Fig. 866, and the pipe clipped to the front as at K.

The barrel may now be fixed, which is done after the suction-pipe is soldered on to the tail-pipe. The method of fixing the barrel is by bolting the lugs down upon the stage in such a manner that the piston or bucket-rod may work quite upright within the barrel; for this purpose, let fall a centre plumb-bob through the stages above and to centre itself, and plumb over the centre of the copper pump-rod E, Fig. 859, so that the whole line of rods may be made to work plumb. Having the barrel fixed, select an air chamber. Now solder on your air chamber to the chamber of the pump, or, first solder a piece of rising main on as shown at Fig. 859, and fix the air chamber by means of a taft or flange joint as at Figs. 859 or 868, and continue the rising main to the cistern, or where you require it.

Take notice that you should have some means of emptying the pipes in case of frost. This may be done as shown in the Fig. 867, and which is nothing more than a simple ball-cock A soldered into the rising main B C, and worked by rods and a handle G H. The best position for this cock is as low down the main as possible, but not below a tail or other valve. If fixed at W, Fig. 859, it will enable you to expel the foul air by blowing down the main pipe from the cock X, or by placing the hose over the mouth or end of the rising main.

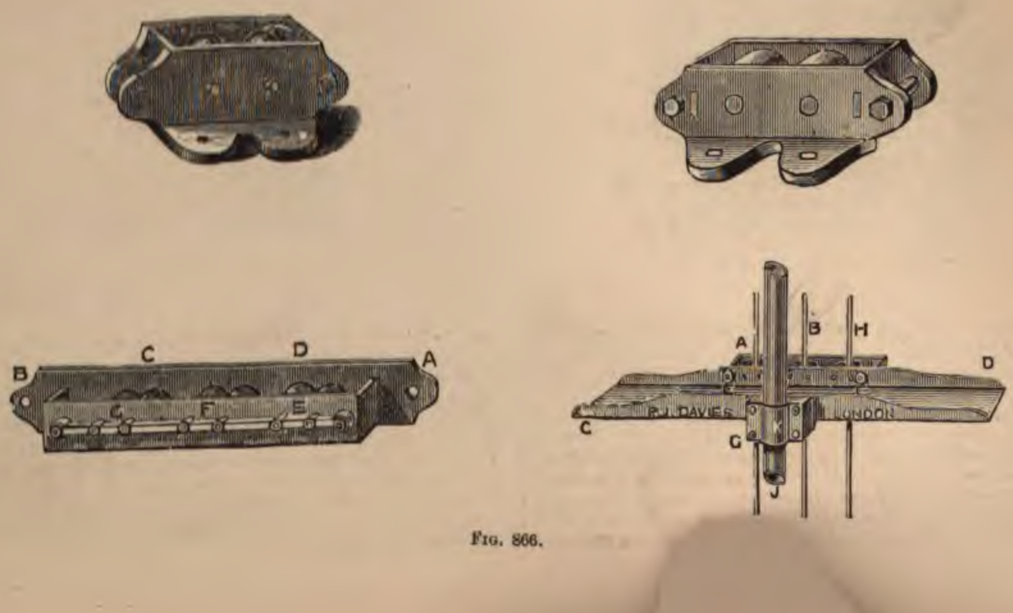
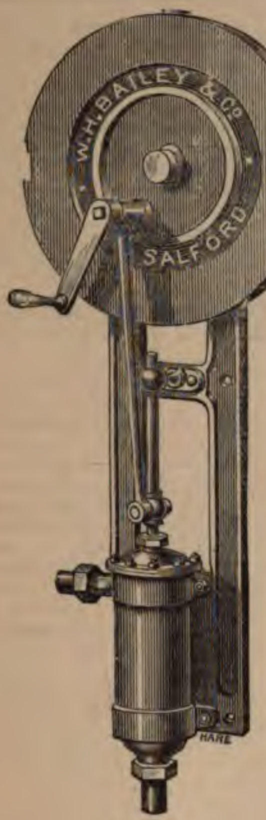


Fig. 866.



AIR PUMP.

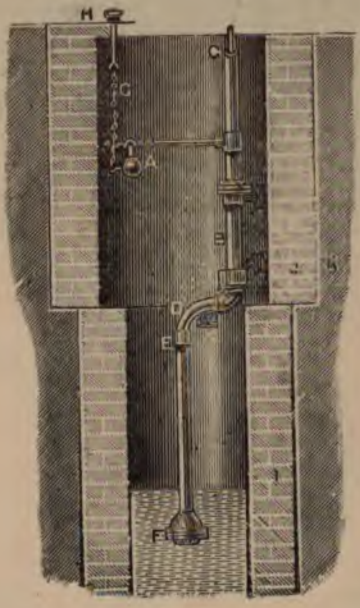


FIG. 867.

Foul Air in Wells.

(*Also see Fig.* 814.)

Now we are engaged upon the fixing or repairs, here will be a good opportunity to introduce the foul air pumps.

There are many ways of clearing foul air from wells; and having suffered through this, the plumber's deadly enemy, I feel always on the fight with it, and have made many kinds of machines to battle with it, and have again shown you in Fig. 867 how to get rid of it. Simple ⅜in. tubing of rubber placed on the wind cock or on the union is all you require if the blower pump be used, either of these machines will clear the most treacherous air in a few minutes from deep wells; but be sure that it is out by your lowering a lighted dip tallow candle. Fig. 867 is, also, very good to supply cool air into a well or other close place whilst the workman is doing his work. There are other methods of clearing foul air from wells, such as with slacking lime and chemicals, which absorb carbonic acid, *but do not use them, for you are scarcely ever safe with such.*

Warning-Pipes and Pump Fixing Gearing—*continued.*

A ½in. warning-pipe (see WARNING-PIPE, Fig. 858) should be fixed from the top of the cistern to the pump-handle (as shown), and in such a manner that it will give warning when the cistern is filled, care being taken to fix it so that it will drain itself dry, and as a protection against frost, for if this is not done, hours of fruitless labour will often take place at times when the warning pipe is frozen. Having the pump-barrel and pipes properly fixed, the next thing to do is to get the exact length of the rods. This is done as follows:—Put the lever quite down, as shown in Fig. 858, and pull up the copper pump-rod, E, and bucket the full height, or as far as it will come. Now push it down 2in. into the barrel, or past the port or outlet hole, and take the exact length, or you may lift the pump handle right up as far as it will go, then push the pump bucket quite down into the barrel and pull it up say 1in. from the bottom of the barrel, and then take the exact length. Of the two plans the latter is the better, because then it is ten to one if the bucket leather ever comes to within 2in. of the port or outlet hole, or touches the bottom valve. Having the exact length, make the rods and couplings accordingly; they are best fastened to the pump-rod by means of the bow connection, as shown at H, Fig. 860, and also see bow connection at K, Fig. 837. Be sure and screw the coupling tight, so that the top nut does not work off or become unscrewed, otherwise the short travel of lost motion will, by reason of the sudden take up or descent, break or bend the copper rod. Perhaps a prevention against this is the slotted key connection as shown at J, H, Fig. 861, which should be tied with copper wire to the rod by passing the copper wire through the hole in the key, see J, Fig 861, and round the rod; or a taper split key may be used, as shown at Fig. 787.

Wheel-pumps with Vibrating Levers.

We now come to that class of pump which is generally used for deep wells, namely, the wheel pump (see Fig. 868). It may be asked, What is the use of the wheel, does it give power, or what? The answer is simply this, that the fly wheel is to enable you to continually put your work into, and when the work is most required, it gives it out at the instant required, thus you are enabled to continually pull and push forward at the handle or wheel, which again gives it up at each up stroke, thus regulating the work as required at the alternative intervals. A further explanation of this fly wheel is that it is an accumulator of power. Thus you gain no power, still the work being more uniform it appears much easier to do. Nor do you gain anything in power with reducing cog wheels. They simply enable you to use a larger barrel, and so reduces the amount of friction of the cup leathers, stuffing boxes, &c., there being less in proportion with the size of the barrels. In this, Fig. 868, the barrel and stages are fixed in the same manner as those explained in Fig. 859, but, being worked by a wheel, the rods will be made to sway too much. For example, suppose the length of the crank to be 5in., then the path of the crank will be 10in., that means that the top of the rod will sway this distance. To overcome this we use what is known as a vibrating lever, S, Fig. 868, better understood from the illustration, Fig. 869. In Fig. 869, the path of the crank B is drawn as at B T S W. Now suppose the path from B to S to be 12in.—this is what is known as a 12in. throw—it will be clear that the top part of this connecting rod C must rock 12in., that is, across from B to S, and if this goes down to the pump barrel it will rock at the stuffing-box in proportion to the length of pump-rods. The rocking of the pump-rod is an evil which is wonderfully reduced by the use of the long vibrating lever G, Fig. 869. For the purpose of our argument, connect the end D of the connecting rod just 6in. from the rivet or spindle F of the vibrating lever: say that it is connected at 2, and plumb over the spindle F. Now turn the crank B A, which is 6in. long, this will cause the vibrating rod to work from 1 to 2, that is, the 6in. But, instead of making the connection at 2, we connect on to the vibrating rod at D. Now turn the crank A B one round. The other end of the connecting rod D being connected on the vibrating lever will move the 12in., but will be kept at a distance from the spindle F, and will only be allowed to rock between the space from 6 to 7, and so on in proportion to the lever, so that the longer the vibrating lever S, Fig. 868, the better. Of course, the pump rod J is connected to this lever at E.

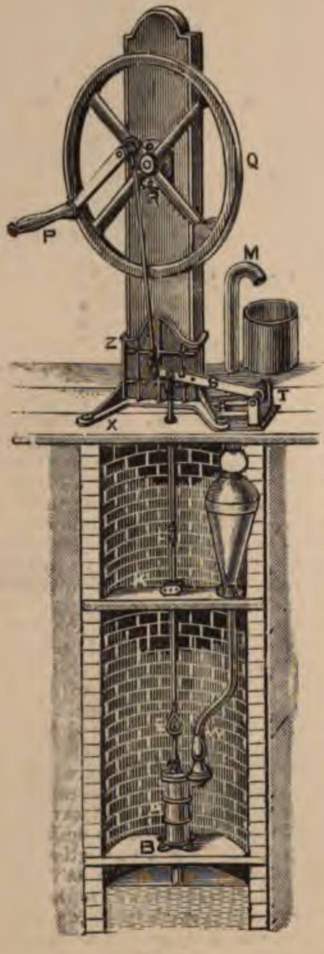


FIG. 868.

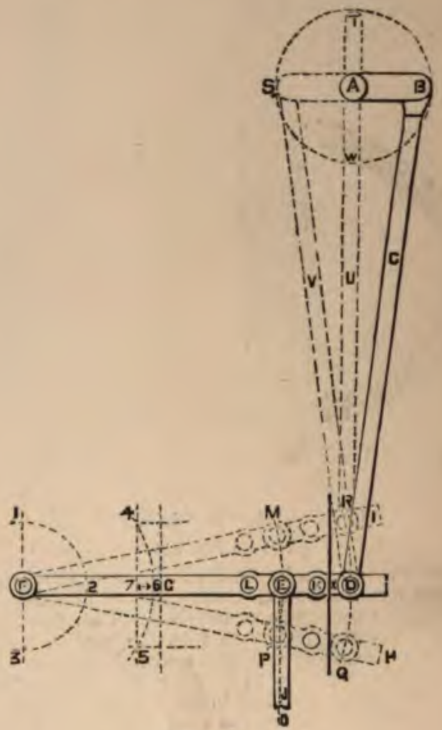


FIG. 869.

Well Rods, &c.

Drilling holes in the vibrating lever. This must receive due attention in order to get the right length of pump stroke (*important*), or you may find the lot torn up, or the rods bent, when the pump is first put into action.

It will be seen that the leverage of the pump may be reduced or increased according as the holes are drilled. Suppose the well-rod J, Fig. 869, to be connected at K, the stroke of the pump must be longer; but if at L so much the shorter. Now reverse the order, and put the connecting rod on to the hole L, and the well-rod on to the hole D, the connecting rods will then cause the well-rods to take a much longer stroke, and in due proportion to the difference in distance between the centreing of the two rods D, F, and the centre F.

Parallel Motion Slings.

In Fig. 870 (which is fixed by blocking behind plank), the sling is made to work parallel. The sling assists to steady the rod by reason that it works close up to the shaft of the fly wheel, and so prevents it from moving only in a perpendicular direction. It is not at all necessary that the connecting rod should be jointed below the stay eye, as shown, as this may be connected above, and thereby a longer connecting rod used, which would be better for the mechanical action, as there would not be the amount of friction against the sides of the guide eye or sides of the sling.

This pump is made in a first-rate style by Messrs. Fell, and is a very handy pump for many purposes. It is also fixed on a pedestal, as at S, R, Figs. 868, 890, and also at Fig. 897.

The Rod Guide and Sling Gearing.—Figs. 871, 872, 873, 874, 875, 888, 889, and 890.

We have seen the action of the vibrating levers; let us now examine the rod guide and sling gearing, for which see Figs. 829, 841, 845, 858. In Fig. 871, we see the same kind of crank-motion given at R, as at R, Fig. 868, but the other end of the connecting rod in Fig. 871 is connected to a joint on the sling at B. For an enlarged view of this, see Fig. 872. A is the guide generally screwed on the plank, and plumb over the pump-rod. B is the sling and guide joint-pin. E is the guide-rod, and V the sling, and connecting rod F. It will be seen that if the crank H, and top end of connecting rod travel in a circle or path, say, of 10in., the other end being jointed at B, must, by reason of the rod and guide, work only in an upright or perpendicular direction. The crank is now in the act of pulling the pump-rod to the right, or otherwise pushing it down, and

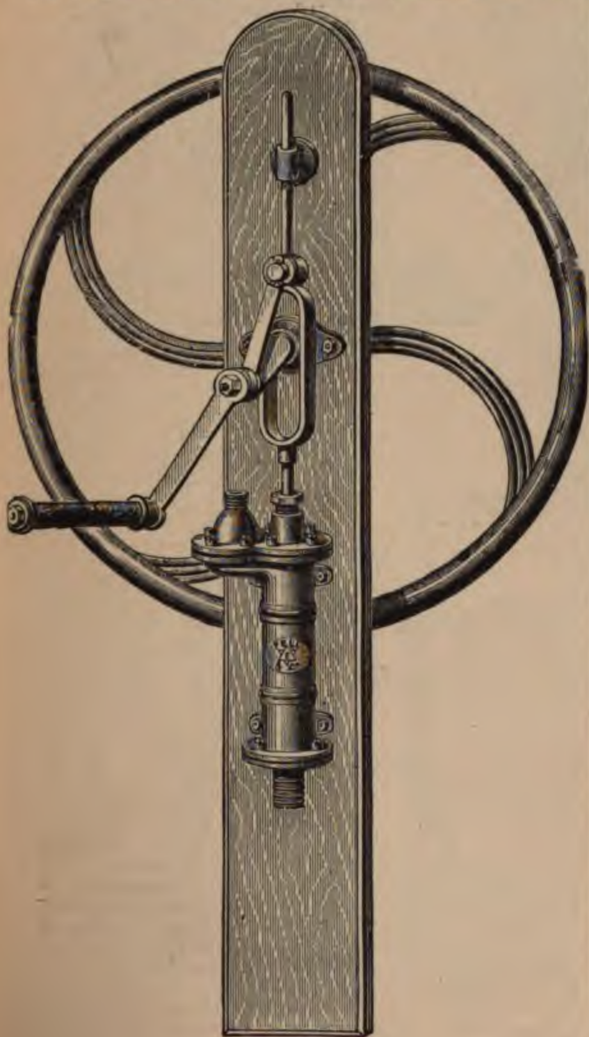


FIG. 870.

FIG. 871.

consequently there is a certain amount of friction between the eye of the guide and the guide-rod, which will be in exact proportion to the length of the coupling-rod, and the length of the sling, together with the weight to be lifted. Therefore, as before stated, the longer you can make this connecting rod, the better and easier will be the working of the pump. For this reason, the guide-rod and sling is often fixed within the well, and across the stage, as at K, Fig. 873. R and S represent the top stage. These guides should be kept well lubricated; sometimes frictional

FIG. 872. FIG. 873.

rollers, pulley shaped, are used, with their bearings working in oil cup boxes, see Fig. 866. Let us now refer to a properly constructed set of three-throw rigging, suitable for a well, say, 100ft. to 500ft. deep; such a set is illustrated at Figs. 874 and 875. Fig. 874 illustrates the rods, guides,

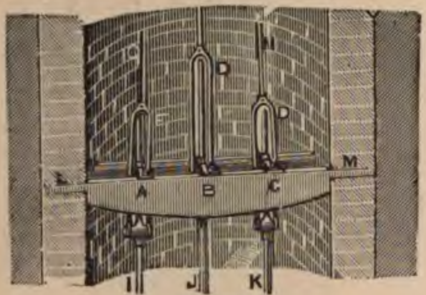


FIG. 874.

and slings, as they should be when at work. A, B, C illustrate the manner in which the guides are fixed on girder stages, and L, M the fixing of the stage into the brickwork. But in Fig. 875 the stage is fixed very differently; it rests upon the shoes, see A, E, B, Fig. 833. The guide-holes are cast upon the stages, and are bushed with brasses for the guide-rods to work through, and this is what is known as a gridiron stage with guides. When such stages are to be used, they should be fixed before the barrel, and the barrel fixed to suit the guide-holes. At N, Q, Fig. 875, is shown

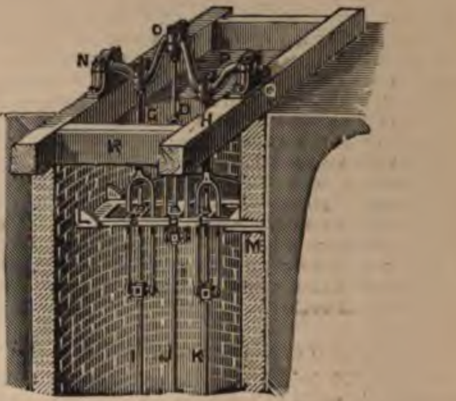


FIG 875.

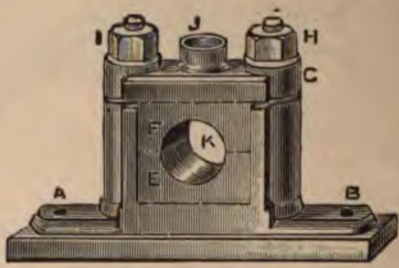


FIG 876

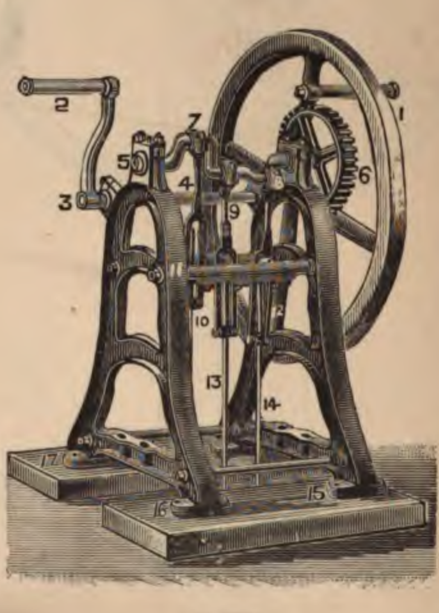


FIG. 877.

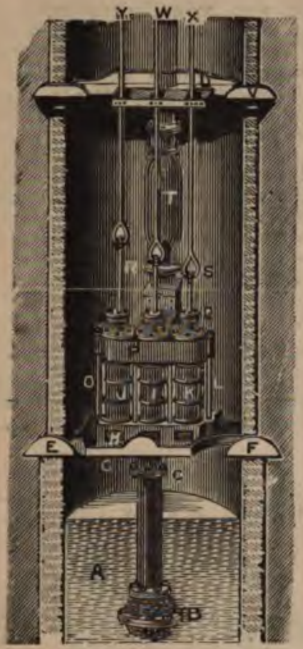


FIG. 878.

plummer-blocks, with gunmetal bearings generally made for 1½in. journals, a side view of which is illustrated at Fig. 876. G, Fig. 875, represents the connecting rods, coupling, and bushes or brasses for fitting round the crank. In this set of gearing, the plummer-blocks are screwed down upon a wood frame, R, Q, &c., for horse and other power; but the same kind of thing is often done upon a cast-iron frame, as illustrated at 4, 5, 7, 8, Figs. 877 and 922.

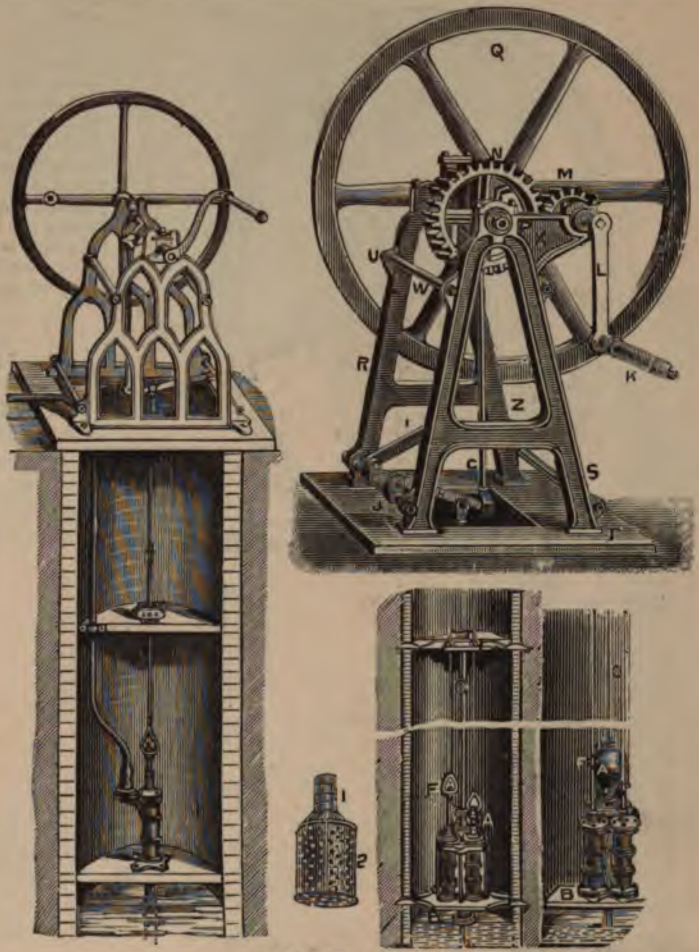


FIG. 879.

Cast-Iron Frames.

These frames are made suitable for single, double, or treble throw cranks. The frame at Fig. 877 is a treble throw, with compound gear. The handle 2, and flywheel (note that for a reason, hereafter to be explained, the handles are in this diagram shown wrongly, see Fig. 881), are shown fixed upon a countershaft 3, and work as follows: Suppose the countershaft to have a pinion or small wheel, as shown at M, Fig. 879, having, say, twenty teeth, leaves, or cogs, and which runs into a large spur-wheel 6, fixed on the crankshaft 5 (Fig. 877). Now, suppose this large spur-wheel to have 120 teeth or cogs, turn the handle six times round, and the cranks will make one revolution, hence we say that the frame is geared for six to one, which is a general thing to do for easy working. Now turn back to Fig. 829. This lever is usually made 16in. to 18in. long, and to the proportion of the radius or throw of the crank. Suppose the pump-crank to give a 9in. stroke, that is, a 4½in. crank, and the handle leverage to be 18in., here the leverage is multiplied four times, or four to one. But suppose the crank to be a 10in. throw, then the leverage is as 18 to 10. But suppose the leverage to be 16in. and the crank 4in., or the throw 8in., then the leverage will still be four to one, and if a man puts 25lb. on the handle, which he should do, you get the 25lb. multiplied by four = 100lb. Now refer to Fig. 877. You saw that the wheels were geared for six to one, and that the leverage on the handle over the crank was four to one. Put the two together, and what power do you get upon one of the rods, supposing the other to be away? First, by the winch you gained four times 25lb. = 100, then, with the cogs you gain six times, which makes a total of 600 times or 600lb., which power will, roughly speaking, work a 3in. pump at a depth of about 190ft., or a 5in. at 70ft., or three 2½in. pumps at a depth of 90ft. Supposing the buckets to be drawing all at once, two out of the three pumps to be always on the lift, the 600lb. will work two 3½in. pumps at a depth of 70ft. Let us further examine this deep well frame (Fig. 877), or a treble throw cranked frame, with guides, guide-rods, and slings (as shown at 9, 10, and 12), connected close to the cranks, which I particularly object to, because they require constant attention for oiling, &c., or they will be very noisy; they make a kind of cu-uting noise or sound which is very disagreeable, to say nothing of the extra labour which is caused by friction.

In Fig. 879 the vibrating levers, H and I, are used, and will, if made long enough, reduce the friction to a minimum, and bring the well-rods to almost a parallel with each o

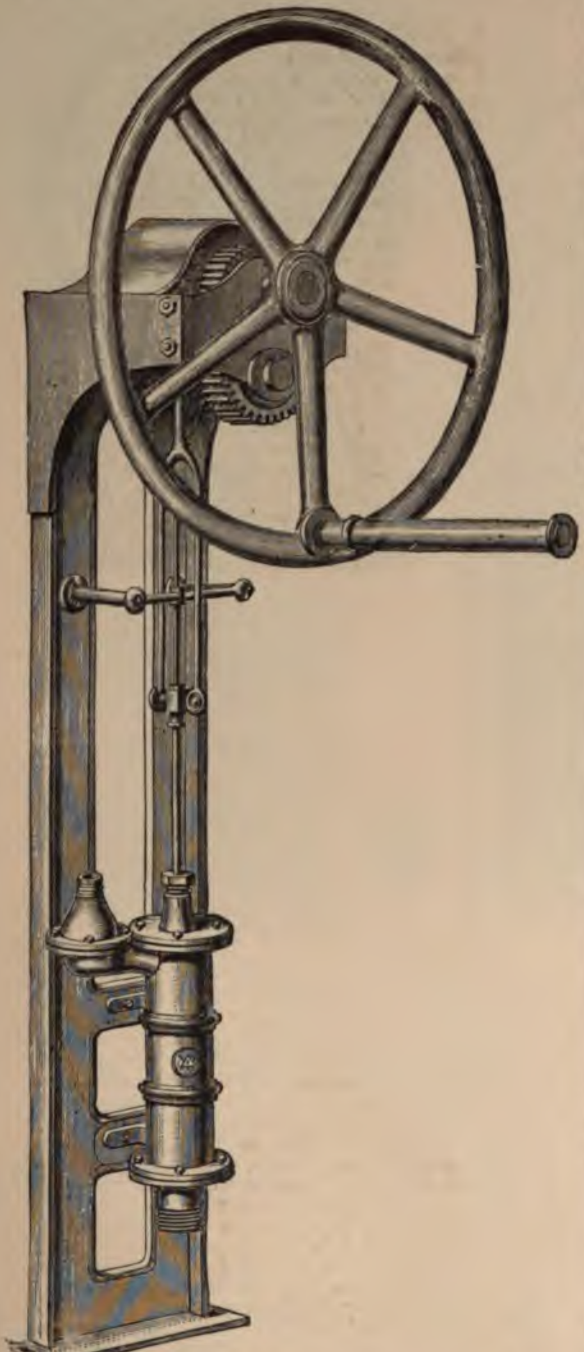


Fig. 880.

In this frame the pinion-wheel **M** may be seen, as also the large spur-wheel; by reason of its being a side view the cranks are not to be seen, but by looking at the two frames (Figs. 877 and 879) the whole of the working parts required may be seen, although they are of two distinct patterns. Here it may be as well to mention that although the above frames have two or three cranks, it does not necessarily follow that all the barrels are always to be used at once. It is an easy matter to disconnect one or two of them, and work with the other; in fact, sometimes, it is Hobson's choice. There are many methods of gearing pumps according to circumstances. For instance, there are shallow wells which above ground have a long vertical rising main, perhaps from two to three hundred feet in height; here the barrels can be fixed above ground at 13 and 14 (Fig. 877), because the guides are close to the cranks. Another method is that which is shown in the diagram (**Fig.** 880), or in many other ways. See **Fig.** 895, also **Figs.** 881 and 839.

The Square Frame for Boarding Round, &c.

At Fig. 881 is an illustration of the square frame suitable for boarding round and covering in the well. It is an old-fashioned frame but a very good one, and answers two purposes. Although it is shown without compound cog wheels, they are often used upon this frame.

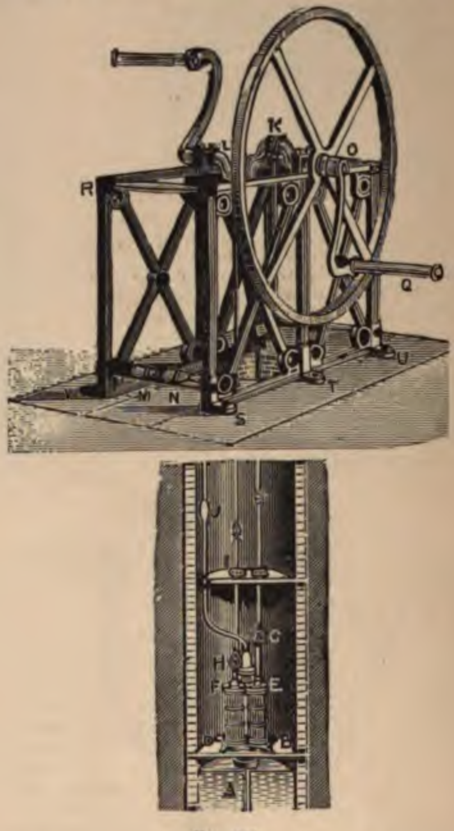


Fig. 881.

The second use of this frame is, that the cranks and shaft may be removed from the bearings, and a properly journaled drum with rope fixed for raising or lowering the workman, *to bring him up top without knocking his head against the stays of the frame.*

Covered in Circular Frames (see Fig. 882).

This is a frame much used for public wells, and may be seen in the old squares of London, and in many towns and villages throughout the country. The framework is formed as shown by the side standards, and the top bent or cast in pieces to the shape. The flywheel generally works inside, and the handles fixed on the spindle and journals as shown at K. There are several of these frames about Hornsey, one at Crouch End, to this day, a public well, which I have personally repaired many times.

Pump Counters and Indicators.

Having explained the action of the rotary pump, it will be as well, before I proceed further, to explain the indicator or counter. For this refer to Fig. 883. This instrument is for the purpose of recording the number of strokes or revolutions which a pump has made. These counters are generally fixed on the pumping machinery in workhouses, jails, &c., for the purpose of recording the amount of work done by those having to do such work. They may be attached to the vibrating lever or shaft, as shown at E, Fig. 883. E is the connection, which in this case is simply an eccentric, and which is nothing more than a circular plate or wheel not

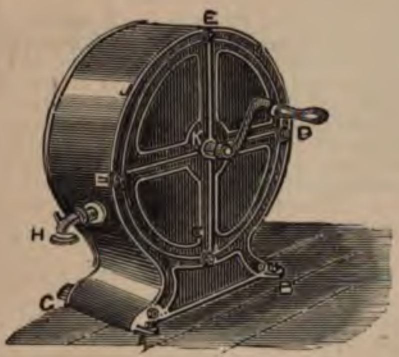


FIG. 882.

fairly centred, and fixed upon the shaft where it is made to move about a centre of motion, as shown on the shaft at C. Round this plate or uncentred wheel is fixed a hoop which exactly fits the plate or wheel, and to this hoop is fixed the connecting rod H, which is also connected to the lever of the counter as at I. It may be seen that as the shaft F, C, revolves, so will the eccentric, and by reason of it not being centred upon the shaft, it will cause the connecting rod to move in a backward and forward direction, which will be in due proportion to the throw of the eccentric, viz., through a space equal to the difference in the centreing of the plate or wheel upon the shaft. Suppose the counter to be fixed as shown, and all to stand at zero. Now give nine turns and the index J will indicate 9. Another turn will bring it to 0, and R will register 1, and so on, 1 for every ten turns. Now suppose the shaft to be worked for one hour at the rate of 25 revolutions per minute, this, when multiplied by 60, gives 1,500 per hour, and this number will be registered as shown on the index, for two hours 3,000, and so on. When the fourth figure has indicated 9, then the fifth figure will register 1, which may be 10,000, [illegible]d so on. But [illegible]se it to stand at say 86,532, and that

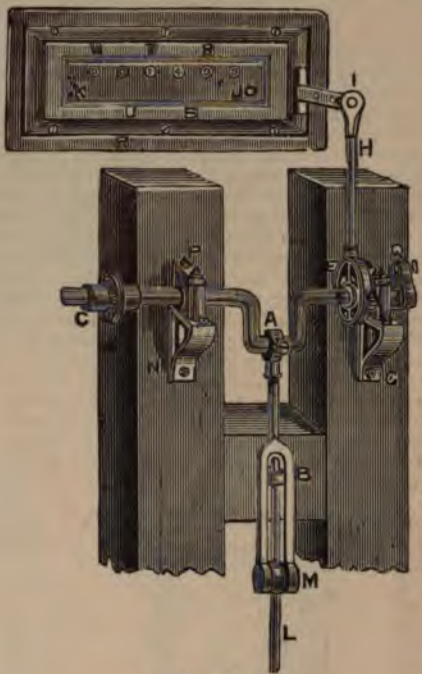


FIG. 883.

it is required to commence pumping, and that it is required to be known what quantity of work has been done after one hour's pumping; at 25 strokes per minute, here you will get another 1,500, added to the 86,532, which will make the register stand at 88,032. But suppose it is required to know the amount of work done in any intermediate time, or after a long turn of pumping, say that the register before the commencement of the work stood at 88,032, and that after the work is done it stood at 97,011, here, if you deduct the former standing figures from the latter you will have a balance of 8,979—the amount of work done. So that with such an apparatus no cheating can take place.

FIG. 884.

These counters are made by Messrs. Bailey to various patterns. Fig. 884 illustrates a round one made by Messrs. Bailey, which is fixed similarly to that shown at Fig. 883.

Water Depth Indicators, or Proving Depths of Water.

Sometimes the amount of labour is ascertained by Bailey's simple method of lowering a line and plummet into the water, to see how much the water has been lowered within a given time, or by the pumping into a tank where a float or other contrivances can be used.

In places where floats cannot be employed Bailey's patent pneumatic indicator may be used, as shown at Fig. 885. This consists of an indicator joined to a kind of diving bell by means of a small-sized compo. or rubber tube. The bell is placed at the bottom of the reservoir in which has to be measured the depth of the liquid. The air contained in the bell cannot escape, and is therefore more or less compressed according to the depth of the liquid. This compression is transmitted from the bell to the indicator through the tube, to long distances, correctly and instantaneously. The mercury or the hand on the dial, Fig. 886, shows the depth of the liquor in feet, or any variations in the level that may take place. The action of the "Tell-Tale" is not interfered with, either by severe frosts or excessive summer heat. The small tube is never clogged up, as nothing but air passes through it; no liquid can ever get inside if the tubes are sound.

FIG. 885.

This depth indicator can be employed to indicate the depth of water in various places at one and the same time, it only being necessary to connect small branch tubes on the main tube, one bell being sufficient for twenty or more dials, which may take the form of that shown at Fig. 885, or that shown at Fig. 886.

When fixing these indicators the following rules should be observed:—First find out if there are any leakages at the joint with the indicator, or in the length of the pipe

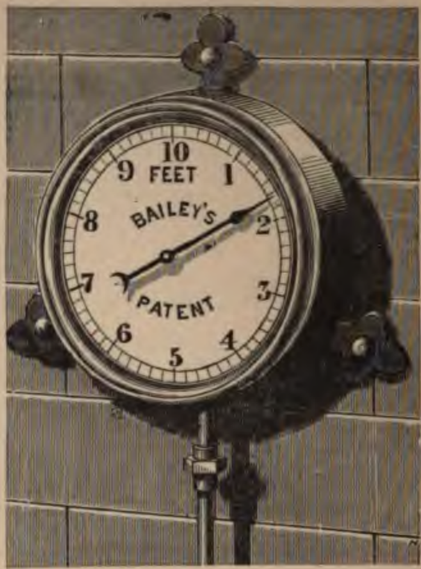


FIG. 886.

itself. Fill the reservoir with liquid and plunge the end of the pipe to the bottom, the indicator will then immediately register some number or other, and at that it ought to remain. If after about five minutes it does not work back, you may conclude that there are no leakages, and that the apparatus is in good working order.

Care should be taken to let the bell and pipe drop vertically into the water, and then the indicator will at once register the height or depth of the liquid. To ascertain when cisterns are full or empty, floats, working electric, or other alarms, are also used.

Testing the Pressure of Water on Pipes, Mains, &c.

Sometimes it will happen that you may require to know the pressure of water in a pipe, and you cannot measure the vertical height. In such cases you can employ a pressure gauge, as shown at Fig. 887; such gauges are made by Messrs. Bailey, to give the pressure in feet and pounds on the same dial.

FIG. 887.

Horizontal or Rocking Shafting, &c., for Distant Wells, &c.

We now come to horizontal shafting for deep and other wells, for which turn to Fig. 888. A is the ordinary wood or iron stage, upon which the pump-barrel is screwed or bolted; B the bow coupling; C, the roller girder; D, the pump-rods carried up to E, which are connected as if to the vibrating lever, &c. At this joint E is a crank formed on the horizontal shafting, which works or rocks on two or more plummer blocks, as at F, G; and at the other end is another crank, which must be bent over on the same side, as at E, otherwise the hand-stroke will give the back-stroke to the pump, unless otherwise arranged.

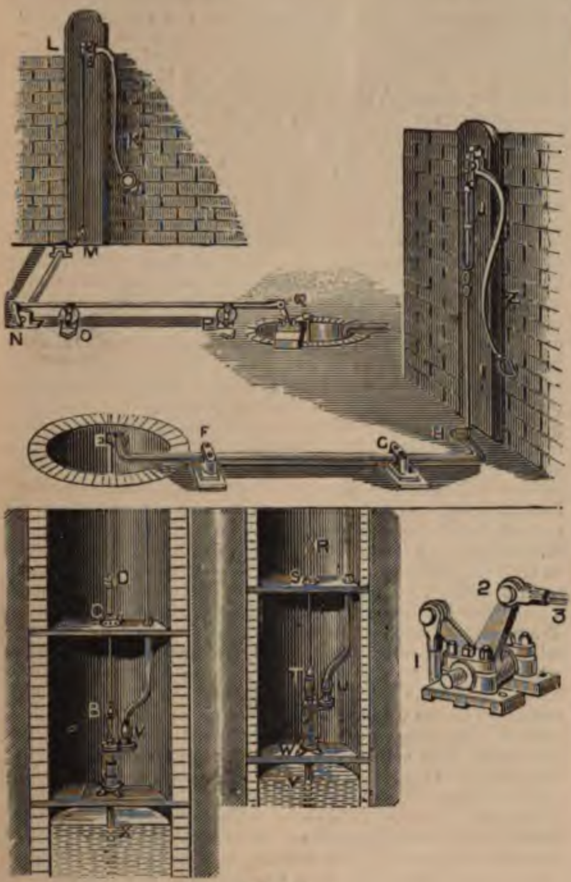


FIG. 888.

The crank H is fitted to the connecting rod I of the handle by means of the guide-rod and sling; the latter of which, in this case, is utterly useless, and will in short lengths of pump rods, as shown from H to J, only prevent the crank H from oscillating, that is if the guide fits the eye anything like properly; simply because the crank oscillates, and the guide is to prevent the rod from swinging. But notice the difference at the pump-handle K, L, M. Here the handle is connected direct into the cranked horizontal shaft at M, also the shaft is cranked at N, but with an upright crank and which is again c o the reciprocating shaft N, Q. L, M rod is fitted right, and will work properly; so would the rod J, I if it were not for the rod sling, therefore do not fit it.

This shaft should run upon upright rollers or runners, as shown at O, P. At 1, 2, 3, may be seen an enlarged view of the crank Q, for connecting the reciprocating shaft to the pump-rod which passes through the roller guides at S. Sometimes the rod R Q is connected to a vibrating lever, which at times is fixed on the stage at S, more especially when the well is a shallow one, and from the lever to the pump-rod with bow-key connection or otherwise. Although I have, for convenience sake, shown both these horizontal rods above ground, yet they are very often to be found in wells from 30ft. to 150ft. below the surface; and when, in very dangerous wells, such work has to be done, great care should be taken to execute it in a good, sound, and substantial manner; and the greatest care should be taken to

FIG. 889.

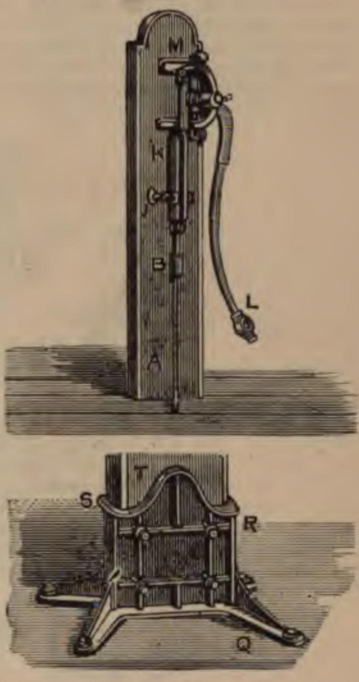


FIG. 890.

fix your cranks, runners, and plummer boxes in a straight line, so that the shafting cannot bind or bite the sides of the brasses, &c. The following is a good rule to adopt: When you have a job of this kind, get all your blocks or sleepers in for the rollers, plummer blocks, cranks, &c., and lay them in position, then place the rods on them, and connect everything you can to work smoothly. Then bore the holes for the bolts or screws to screw down, and fix the blocks without a move. You are then sure to have the rods and shafting to work without grinding or biting the shafting. Such levers or pump-handles are fixed on to the plank, as shown at Figs. 889 and 890. The latter is a very simple method of fixing the lever through the plank, and also the guide K. These planks are often mortised into a plank or sleeper over the well, or otherwise let into an iron shoe, as shown at K, X, Z, Fig. 868, and at S, T, R, Fig. 890.

Compound Handles for Pumps.

Sometimes compound lever handles will have to be used for places such as brewers' boilers, water carts, and such like, or for places where the spout of a jack or suction pump is five or six feet above the level of the ground. For argument sake, or to show what is meant by this, refer to Fig. 822. Suppose a handle or lever to be fulcrumed at the astragal E, half way up the body of the pump, and the handle J to be attached by links or otherwise to the first handle, it will be plain that on actuating the lower handle that the upper handle will be worked, thus enabling you to use an ordinary jack pump, when otherwise you would have to use a lift or plunger pump.

Distance Pumps.

Sometimes it will happen that you will want to get water from a long distance that you cannot fetch it by atmospheric pressure owing to the level of the water being "out of draught;" when such is the case you can work with the following methods:—Suppose a well to be 300

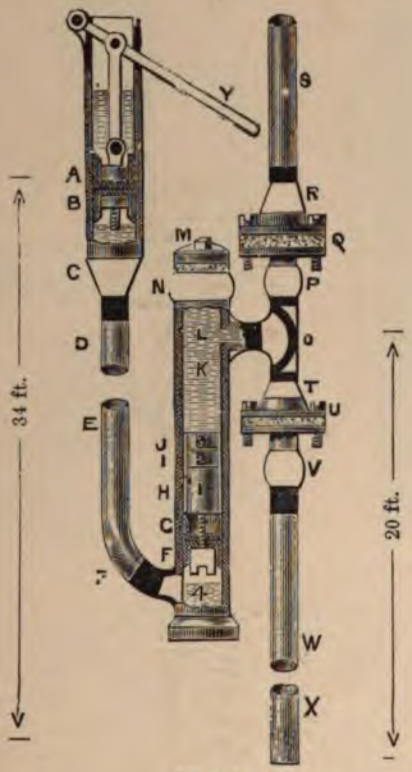


FIG. 891.

yards distant from a house, and, say, 34ft. below. Let A, B, C, Z, Y, Fig. 891, be the plunger-pump barrel without a suction-valve. In this barrel is a double cup leather plunger A and B. D, E is the tail pipe leading to the bottom of the hill, &c. The duty of the plunger at the up stroke, is, if the well be 34ft., to draw the water as far up the suction pipe as possible, say from 20ft. to 24ft. Let E, F be the other end of the tail pipe branched into another lead barrel L, K; within this second barrel, at F, G, is a weighted plunger, 1 2 3, but actuated by water only, which I have denominated my hydraulic actuating plunger. This plunger, having a cup leather F, on the bottom, is free to move upwards, and according as the water is forced from the plunger-pump A, B. Let L be the outlet from the second barrel into a branch valve pipe O; below this branch pipe is fixed a tail-valve, T, U, V, on the suction-pipe V, W, X. Above the branch pipe O is another tail or chamber-valve Q, R, fixed on the rising main pipe S. M is a 3in. or 4in. cap and screw, for getting access to the weighted hydraulic actuating plunger. The action will be readily understood, and is as follows:—First take off the cap and screw M, fill all the pipes connected with the pump, say, by also taking out the plunger A, B, and pouring water down the barrel until all are quite full. Next put the cap on, and fill up the barrel A, B, C, then put the plunger in. At the downward stroke the water within the barrel A, B will be forced downwards, which in its turn will lift the weighted hydraulic plunger F, G, H, I, J. This will also lift the water above the piston through the branch pipe O, and close the suction-valve U, and then open the outlet valve Q, when the water will run up the rising main pipe S. Now, let the handle Y, be lifted. This will relieve the water below the hydraulic plunger, to the extent of, say, 24ft.; when the hydraulic plunger, being weighted to overcome the remaining few feet, will fall, and the two plungers combined will cause the pump to work. Of course, it then follows, that if these two plungers act properly, the ascent of the handle will cause the valve Q, to close, and the suction-valve U, will open, and allow the water to be forced up the pipe equal to the ordinary atmospheric pressure. If the hydraulic action piston be weighted to the column of water between F, and A, then the piston A must be lifted in proportion to the weight of the water within the suction-pipe V, X. I should add that the hydraulic action plunger must be weighted sufficient to allow for friction, and a fair allowance for putting the water into a moderately quick motion. I make the plunger, F, G, of elm; only one cup leather is necessary, the bottom one, because the plunger cup leather B does the work of the one at G. The weight or weights are made of solid lead, about three times as long as they are wide, and may be put in at the cap M, but not until the barrel L, K is full of water. To take them out use a pump-screw, or fix a cap at the bottom of the barrel. When weighting the plunger, F, G, it must be borne in mind that you must allow for the difference of its weight when in water to that when out; or, in other words, and according to the rules of hydrostatics, the plunger being immersed in the water will not exercise so much power by exactly the weight of the amount of water which it displaces. The cup leather F, must never be lower than that shown to interrupt the inlet water way 4.

The pump, Fig. 892, is somewhat different from that shown at Fig. 891. This pump, which I have also invented for an American deep well, does not depend upon the weighted plunger for filling the barrel (viz., the suction). It is very simple, and anyone having a knowledge of pump work can fix it. It works as follows:—The top barrel is valveless; now by turning the handle of the wheel, the double action pump bucket first sends the water one way through the barrel, and then another. Suppose the connecting rod to be just on the back stroke (viz., going downwards). This forces the plunger bucket and the water from the bottom part of the barrel, and through the BACK STROKE PIPE and into the actuating second barrel J, and so sends the actuating plunger bucket downwards, and with it the pump rod N, which in its turn forces the pump bucket down. Now, suppose the handle to be turned so as to give the hand or up stroke to the top bucket: this forces the water from above the bucket in the top barrel and down the HAND

STROKE PIPE to the actuating or second barrel at K, and so forces the plunger bucket up, which also brings up the pump rod and pump bucket, which, of course, causes the water to flow up the rising main to any required place. It is obvious that this pump may be worked at any distance through the HAND AND BACK STROKE PIPES, and that the actuating barrel K may be made to any size, and thereby compound power may be obtained. I have fixed four of these pumps, and think that they are the only four ever fixed. The speed for working the pump should not exceed 20 strokes per minute. Of course there are various methods for fixing such a pump as here illustrated, which can be varied to suit circumstances. It is all the better to take a ¾in. pipe *with stop cock* off the rising main at about K, to the bottom of the barrel K, to keep it supplied with water to about 10 *spots per minute;* Fig. 794 must be fixed on the main above the ¾in. supply pipe. Be particular about turning the tap on to supply only the 10 spots as the pump will otherwise be taking too much water from the rising main.

FIG. 892.

Double and Treble Lift-pump Barrels.

We have seen how to fix many of the ordinary pumps now used, but there is still left to be explained the double and treble barrels. Let us examine Fig. 893. This is the double barrel, with tail piece and chamber-way B, and with chamber-box and ports, E, as may be seen. The pump-rods are keyed on, as shown by the keys at F and E, and the barrels screwed down upon the pump stage by the lugs B, &c. The method of fixing is precisely the same as in fixing a one-barrel pump. All that has to be done is to fix

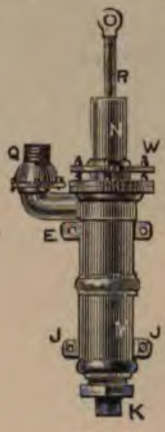


FIG. 894.

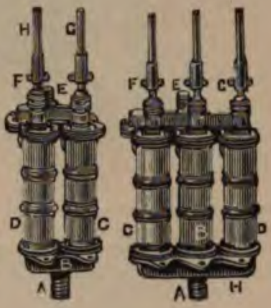


FIG. 893.

the barrels upright, and keep the well-rods to work plumb over the ends of the bucket of pump-rods, at the same time keep the well-rods quite straight, and free to work up and

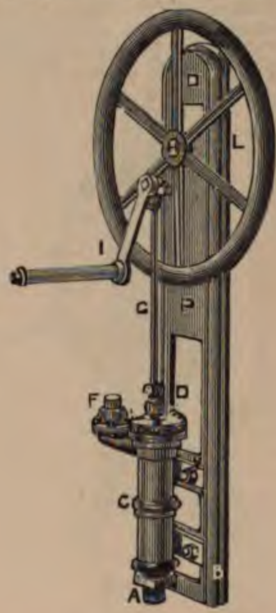


FIG. 895.

down, and without too much play to cause too undue vibration. Take care that the pump buckets do not bump against the bottom or top of the barrels by the crank throwing or lifting too high, or otherwise dipping too far into the barrel. By paying attention to the rules laid down on the settin[illegible] of single pumps this may be avoided. The [illegible] that have been made concerning the doub[illegible] the treble barrels.

Plunger and Bucket Pumps—*continued.*

Let us now return to Fig. 851. Here is the plunger and bucket pump. I have already explained its action; but

FIG. 896.

there is now something more to be explained: for this refer to Figs. 894 and 895. The former illustrates a hollow plunger and bucket pump. The coupling rod R is connected to the bottom of the plunger; by so doing, the coupling rod is longer than if attached to the top of the plunger as at D, Fig. 895. It may be seen that the plunger, being thick and with a wide surface, that it is necessarily

FIG. 897.

very strong. It also follows that, in consequence of the length of the stuffing-box and stuffing, that the plunger is kept upright, and, by its working on this long surface, that the grind upon the packing is reduced to a minimum, and consequently may be connected direct without guide-rods, etc., to the handle of the pump as shown. If this plunger and bucket pump are fixed about 6ft. down the well, and the frame and wheel, Figs. 896 or 897, used, the pump will work easier, because the side or lateral friction is again reduced by reason of the vibrating rods.

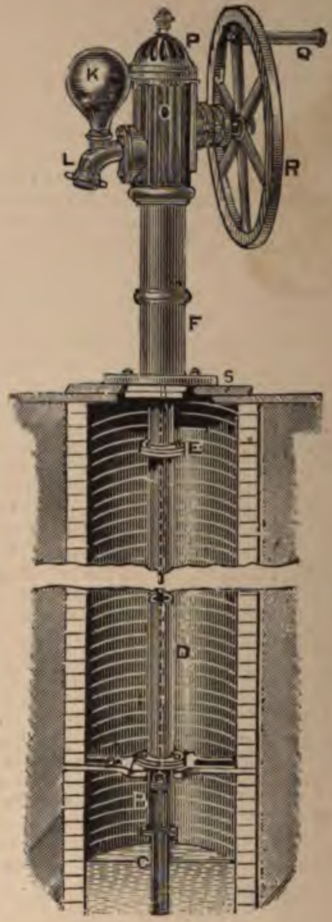


FIG. 898.

Deep Well Iron Pump with Flywheel and Compensating Head, having Air-Chamber and Nozzle for Hose.

This very handy pump is illustrated at Fig. 898, and from what has been said about the ship pump (Figs. 854 and 855) its action will be readily understood. This pump is inexpensive, and is made as follows:—Upon the iron stage A rest the flanges of the pump; this stage steadies the pipe and pump-barrel, and prevents them swaying about in the well whilst the top stage takes the downward thrust of the pump, the top part of which is bolted down on the top sleepers, as at S. The crank action is precisely the same as in Fig. 854, excepting that in this figure (898) there is no guide or guide-rod required, and it has a second air-chamber which Fig. 854 has not, but which was spoken of when describing that figure.

WORKING PUMPS.

Having now described the various kinds of pumps which the plumber has to fit up, my work will not be complete without showing and describing the useful methods of working such pumps. There are hundreds of different methods of working pumps, from the hand of man to the bough of an oak, by wind-mill, stream, steam, gas, oil, or petroleum engines, or even a pump can be worked by the hydraulic ram (see Fig. 957). First let us examine the well-known means of the water-wheel.

Water Wheels (Overshot).

Fig. 899.

For the method of fixing, refer to Fig. 899. Here, at A, E, F, G, will be seen an overshot water-wheel, worked by the water flowing down the race Z, B. The shaft of a three-pump frame is in this case connected direct on to the shaft or axle of the water-wheel as shown at M. The one end of this wheel takes a bearing upon the standard of the frame as at O, the other end of the wheel shaft or supported upon a fixed standard, which may be con[illegible] of stone, brickwork, or otherwise, and the *plumm*[illegible] fixed to receive the said axle. It will be plain t[illegible] that if the water-wheel is turned with a sufficient [illegible] water, and the shaft M, N of the pump conne[illegible] direct, or with multiplying or diminishing [illegible] gear, &c., that the pump must of necessity b[illegible] Very little skill is required in fixing such a ma[illegible]

that is required when fixed as illustrated, is to keep the line of shafting M, N in a direct line, and level, and the water-wheel well up out of the tail water K, or at least so that the bottom of the wheel cannot touch or trail the waste or tail water at the bottom of the wheel. In fixing the *wheel race*, bring the end B past the centre of the wheel, and in such a manner that the water will fill up the bucket, and always tend to turn the wheel as illustrated by the arrow between A and E The wheel race need not be a square trough—a pipe governed by a stopcock or valve may be used; but the above kind of race is generally used, because, with this, the water spreads out into a thin layer, and fills up the buckets better.

In some cases, then the race is very quick, it will be necessary to fit a penstock, or diverging board in front, such as is shown at B, Fig. 901, and at such an angle that it will cause the water to play downwards, and into the buckets; but with this kind of wheel, Fig. 899, the race should not have too much fall, or be too quick, nor should the wheel travel too fast. Three feet per second is a fair speed for all overshot wheels. When worked much faster or slower, it is a sign that the proper amount of work is not being done.

If the wheels are very large, say, from 20ft. to 30ft., then they may be worked at double the above speed. But for my part, for all overshot wheels, I prefer the 3ft., and never to exceed 4ft. per second: and this theory is thoroughly borne out by the following observations. That, in certain proportion, the slower a body by gravitation descends when acting upon, say, the external rim of a water-wheel, the longer will that force be spent upon it, and the greater will be the effect. This is precisely the case with the water in the buckets of the water-wheel. For example, suppose the velocity of the stream or the falling body to be 16ft. per second, and the wheel to be travelling at this speed, it is evident that no work is being done, and if the wheel be loaded with work equal to the power of the stream, then it would not move at all; but let it move at the rate of 3ft. per second, and the best work can be obtained.

It will be evident that if you can get, say, ten gallons per minute from a spring or other source, and that the fall be, say, 3ft., that you can with an overshot wheel, as illustrated at Fig. 899, and with pumps, raise a good portion of the water expended to the same height, because when water descends from any level to a lower one, its weight during the descent may be used as a mechanical agent, and therefore—the diameter of the overshot being nearly equal to the difference of the levels of the water,—the wheel will, of necessity (save and except friction, &c.), exert a power or force accordingly. For argument, say that the loss occasioned by friction, &c., is 50 per cent. (thus allowing a very wide margin), then you will be able to raise 50 per cent., or one-half [illegible] similar height of 3ft., and i[illegible] cent., or one [illegible], and so on [illegible] t from a [illegible] pth from [illegible] ice of dis- [illegible] th, which, [illegible] l. Now [illegible] and this [illegible] second. [illegible] wheel, [illegible] lated,

Rag Wheel or Sprocket.

It will sometimes happen that you will not be able to fix an overshot wheel for want of room, &c. When this is the case, and the fall considerable, a kind of chain water-wheel may be worked. This is known as the rag or sprocket

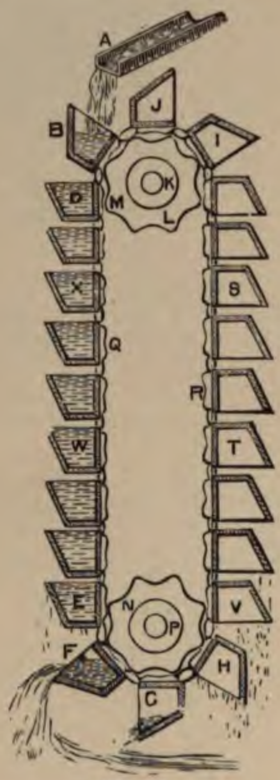


FIG. 900.

wheel, Fig. 900, and when only a very limited quantity of water is obtainable, it will be found exceedingly serviceable.

This apparatus consists simply of two endless chains R, Q, made to hang over a kind of toothed wheel M, L, K, or a wheel having pins or spurs, which fit into the chains as those of watch or bell chains, and steadied at the bottom by a lazy wheel N, P, with the buckets J, B, D, W, E, F, G, H, I, &c., and which may be of any material, though I prefer light galvanized cast iron, about $\frac{1}{8}$in. or so in thickness. The size of these buckets must be in proportion to the fall, the supply of water, and the amount of work required to be done.

The action is as follows:—The water runs from a tap or spout as at A, into the bucket B, D, &c. At first, in order to start the machine, it is necessary to pull this bucket down and allow another to fill, then another, and so on until the water within the buckets has accumulated a weight sufficient to overcome the resistance of the pump or of the weight or load to be moved on the wheel M, L, K, or if preferred the work may be taken off the lazy wheel N, P. This done the water will continue to fill the buckets, which, when they descend to F, G, will empty themselves; and in proportion to the rate of filling, so will be the speed of the rag wheel.

When the fall is considerable, this kind of wheel may be made at a much lower rate than any other kind of water-wheel, and it is a very simple, cheap, and lasting apparatus for working all kinds of pumps. These chains and buckets may be made to work obliquely, such as down the side of a hill, &c.

This machine, when reversed in action, is much used by sewer contractors, &c., for raising water having rubbish, &c., in it, and when such is the case, its action must be that of the user of power; or it must be driven instead of it being the power obtainer, similar to the NORA pump, which see. Also see "Joseph's well."

There are other kinds of wheels which the plumber has to fix for working his pumps. These are the breast or undershot wheels, and although I have coupled them together, they are worked somewhat differently from each other.

This breast wheel is illustrated at Fig. 901, and will be readily understood. Here the water, instead of impinging on the top part of the wheel, meets it about one-third of the way up, as shown at E, L, Q. The race F is built to the same common centre as the radius of the wheel itself, and in such a manner that the sides shall be parallel to the extreme circumference of the other parts of the float boards, S, T, &c. The float boards may be coupled together, and so strengthened, with the two outer edges of the wheel, as at I, S, &c., and so be made to hold the water without allowing it the chance of rushing past the sides of the floats and the wall. When this is the case, the water is imprisoned to the

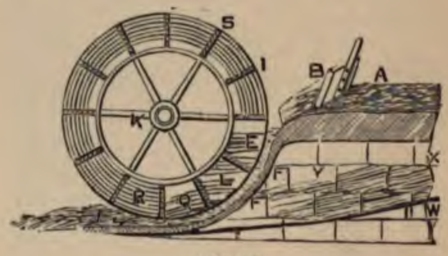


FIG. 901.

wheel, and its useful effect thereby increased. It will be seen that in this wheel the whole force of the water, from the highest point E of the entrance to the extreme tail water at R, can be had; and, at first glance, one would naturally suppose that this rush of water would make this wheel more powerful than the overshot wheel. But this is by no means the case—far from it. The breast wheel is vastly inferior to the overshot wheel, by reason of the waste of water which rushes past the floats, to say nothing of the difference in the height or fall of the water, and other defects which only show themselves in practice. It will be found that in this wheel, for the same amount of work done, as compared with the overshot wheel, that nearly double the quantity of water will be consumed. But as the action of this wheel differs from the overshot wheel, it will at once be seen in order to get at its power it will be necessary to adopt another method of computation. Here, in Fig. 901, at E, the water is required to flow with as much velocity as possible, and to strike the floats with an impetus equal to that of the velocity and weight of the water in its descent. To compute the effect or power of the water playing on a breast wheel, it is necessary in the first place to know the real velocity of the water impinging upon the floats, also the quantity of water which plays upon them, the size of wheel, &c. The breast wheel, at times, must play at a different speed to that of the overshot. The

latter should travel according to time, but the breast wheel should travel in proportion to the velocity of the water. The rate of this wheel should be one-third to one-half that of the water. For example, suppose the velocity of the water to be 20ft. per second, then the wheel should be allowed to travel, say, 7ft. or 10ft. per second, and so on proportionately.

I may add that the difference between the breast wheel and the undershot wheel is shown at the dotted lines F, Y, X and W, which will show that the water strikes the floats under the body of the wheel, and, in fact, by way of a further explanation, the undershot wheel is one that may be worked by tidal action, as did the old water works of London, at the original London Bridge; or, from a stream, or without any perceptible head of water, save and except the velocity of the water itself, and of all water-wheels the undershot wheel is, so far as regards its power, of the least value.

The Turbine.

This is another form of water-wheel, which may be worked in a horizontal position or otherwise, and in point of fact is the water-wheel perfected (also see BARKER'S MILL, Fig. 932).

There are many makers of this useful machine, but I shall only show you those of the best maker of the day, and which I consider most suitable for pump driving purposes, and give you a few hints regarding their theory, selection, and management.

The turbine, which was first brought into prominence, if not invented, by Fourneyion, about the year 1823, is a perfected form of water-wheel.

The great difference between a turbine and a water-wheel is, that in a turbine the pressure due to a column of water is used in turning a small wheel at a high speed, whereas in a water-wheel the water simply falls into the buckets of the wheel and turns it round by its weight.

The nearest to the common water-wheel is the GIRARD, made by Gilbert Gilkes & Co., Ltd., and shown at GIRARD, Fig. 902, Plate 1, and for the description of which I cannot do better than append that of the makers, who say:—When the fall of water is very high the periphery of a turbine wheel must move at a very high speed, and if the revolving wheel is submerged, there is some loss of power in friction of the wheel covers against the water. Again, if the wheel be of so small a diameter as to admit of an arrangement by which it receives the water all round, the speed of the axis must be very high, probably inconveniently so. It is, therefore, in case of a high fall, necessary to make a wheel of such diameter as to suit the speed of the axis, and to construct it in such a manner that it need not receive the water all round, and need not run submerged as does the VORTEX, Fig. 902, Plate 1. The GIRARD turbine has no pressure between the guide blades and wheel, and as the water enters the buckets with no pressure, it is freely deviated by them, and takes a course quite independent of their shape.

The action of the water upon the wheel depends on the angle through which each particle is deviated whilst freely flowing over the buckets, and as these latter are not full, there is no disturbance of the action as they pass in front of or away from the jets.

It will be seen that the water enters through the valve, and passes directly into a distributing chamber, from which it jets on to the buckets of the wheel through grates or ports, varying in number according to circumstances. When there is only one port it can be reduced in size when is scarce, or less power required, and when, as is y the case, there are many ports, a sufficient number of them may be used to suit the requirements of the moment.

The arrangement by which the power is reduced is easily worked either by hand or governor.

Having seen the Girard, we will now examine the principles of the VORTEX turbine, and for this I will refer you to Gilbert Gilkes & Co.'s machine and description. SECTION A, Fig. 902, Plate 2, represents the vortex pressure re-action turbine with cover removed, and ELEVATION B shows the turbine complete, as usually placed at the bottom of the fall: A is the revolving wheel keyed on to the shaft C; B, one of the guide blades; D, the bell cranks and shafts connecting the guide blades with the outside bell cranks and coupling rods E; F, the guide blade gear; G, the bracket and screw for raising the pivot (the pivot cannot be seen in this sketch, see G, G in the SPIRAL VORTEX); H, the wheel cover; I, the supply pipe by which the water enters the case.

The VORTEX, by these various improvements, possesses great advantages over other turbines, inasmuch as the loss of water is reduced to a minimum by the use of these regulating blades, and the power is obtained with a slower velocity of water effected by the peculiar balancing of the centrifugal force of the water in the revolving wheel against the pressure due to half the head, so that only one-half of the fall or head is employed in giving velocity to the water, the other half acting simply in the condition of fluid pressure, hence the velocity of the water in no part of its force exceeds that due to one-half of the fall, and the loss from the fluid friction and agitation of the water is thus materially less than in other turbines where the water is required to act at much higher velocities.

It will be seen that from the principle of injection of the water from without towards the centre, there results another saving of effect, since it admits of the use of long and well-formed channels, by which the water is made gradually and regularly to converge in passing from the outer chamber (where it is comparatively at rest) to the point of entrance to the wheel chamber, where its velocity should be the greatest.

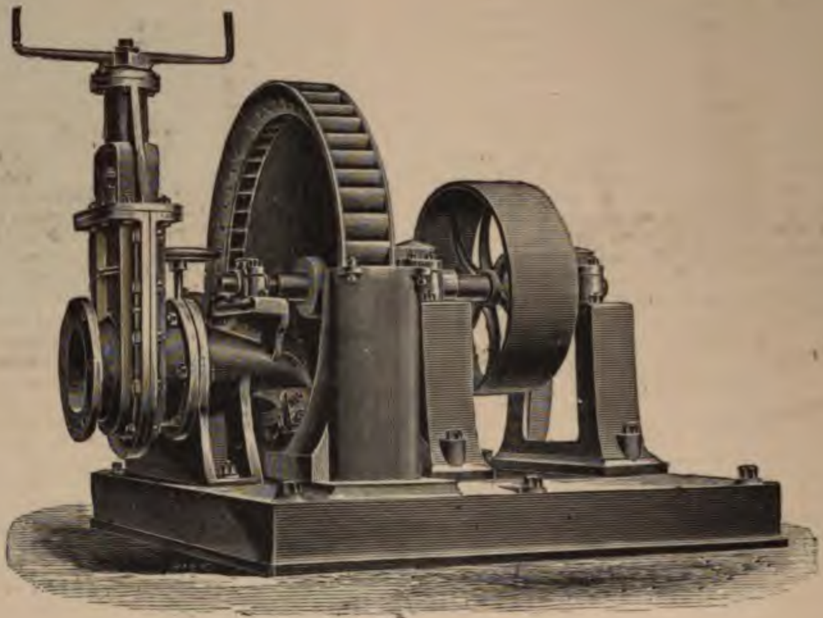
The advantage of these convergent channels for the transmission of water with a minimum loss of effect, as compared with short passages, such as are generally employed in other turbines, is well known.

From the same principle of injection towards the centre, there is an accordance between the velocities of all parts of the moving wheel, and the proper velocities of the water in its passage between the points of entrance and discharge.

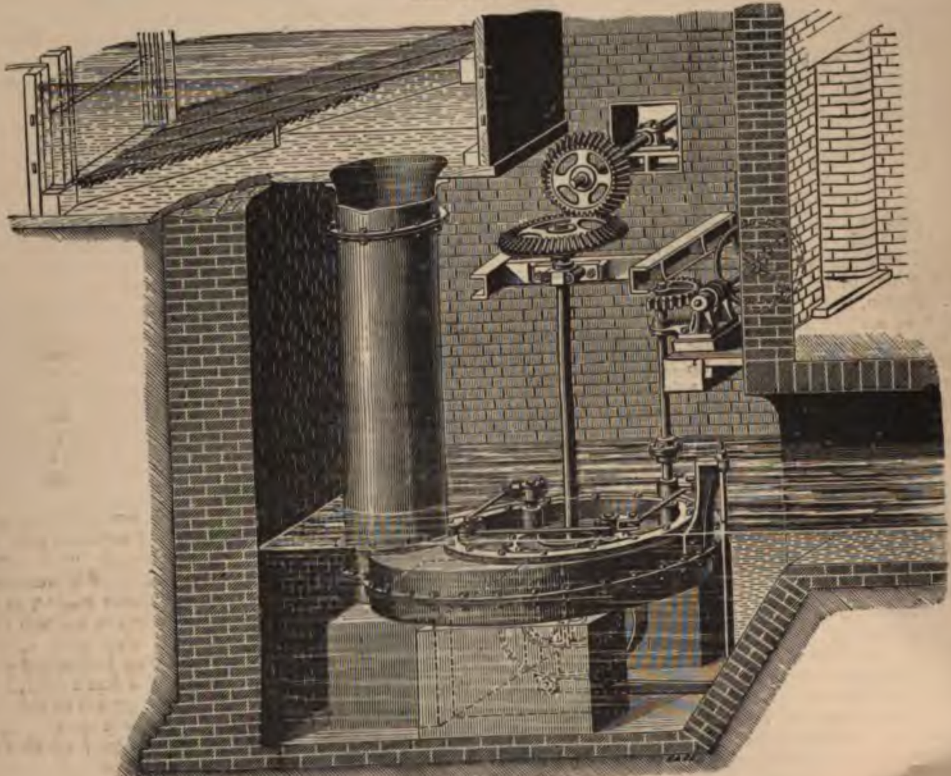
It should also be borne in mind that when the water has its greatest velocity it is admitted to the circumference of the wheel, which is the most rapidly moving part, and when it has, as far as possible, imparted its power to the wheel it leaves at the central portion or axis, which has the least motion; moreover, the water being made to impinge upon the outer circumference of the wheel, meets hardly any loss from impact.

It will be noticed that these guide blades are made movable upon gudgeons or centres near their points, motion being imparted to them simultaneously by a hand wheel, which can be placed in any position easily accessible, and by a very slight motion of these guide blades, the orifices may be opened or contracted at pleasure, and are thus made to suit any quantity of water which it may be necessary or desirable to use. The following important conditions of efficient application of the water are fulfilled:—First, the channels are of a gradually convergent form. Secondly, the water is uninterrupted in its course, and enters the wheel chamber from the narrowest part of the channel, and, consequently, attains its maximum velocity at the point of application. Thirdly, the water is admitted equally to the whole circumference of the wheel.

PLATE 1.



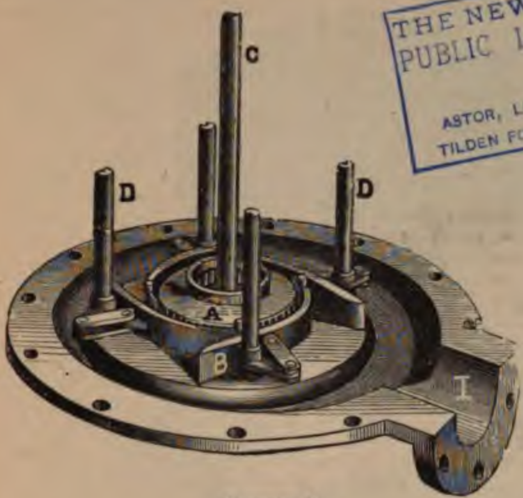
The Girard.



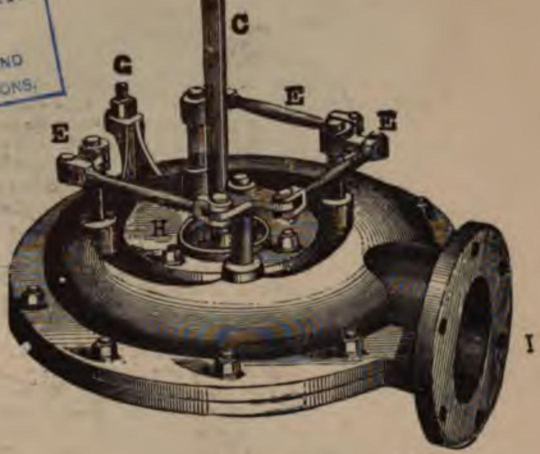
Fixed Double Vortex.

Fig. 902.

PLATE 2.

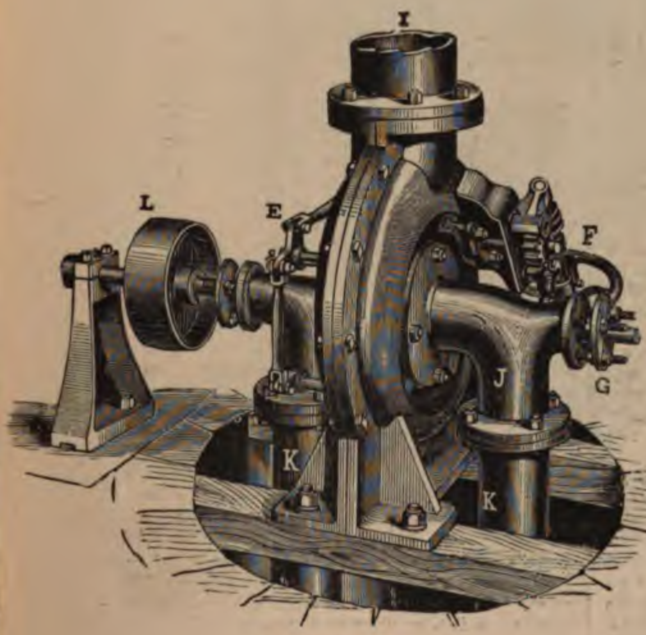


SECTION A.

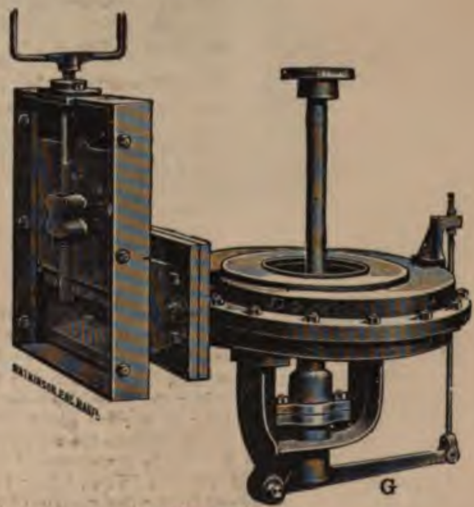


ELEVATION B.

WHEEL PLAN.



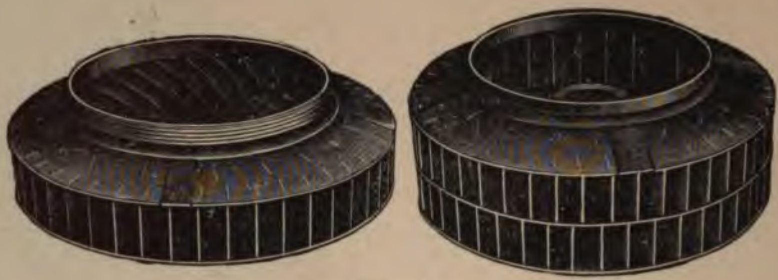
VORTEX AND WELL.



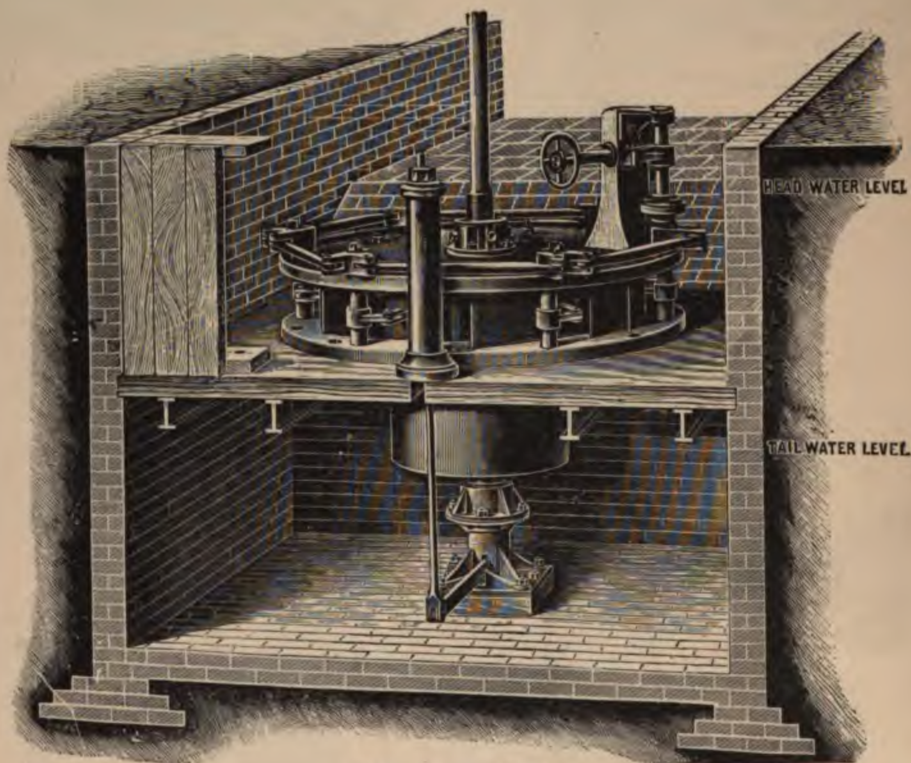
SPIRAL VORTEX.

FIG. 902

PLATE 3.



WHEELS.



FIXED SINGLE VORTEX.

FIG. 902.

In many situations the arrangement of the VORTEX, as at VORTEX and WELL, Fig. 902, Plate 2, may be adopted with great advantage. Thus the wheel may be placed at any height less than 25ft. above the tail race, the fall below the wheel being rendered available by what will be best known as drag or suction pipes, descending from the central discharge orifices into the tail-water.

This VORTEX and WELL arrangement illustrates the supply pipe I to the turbine (K, J, being the outlets which should be continued below the surface of the water in the tail-race), which prevents these drag or suction pipes from too readily emptying themselves. Of course, these pipes may be taken down an embankment, hill, or otherwise. G is one of the glands through which the shaft passes. L is the pulley or cog-wheel from which the power is taken for driving the pump.

WHEEL PLAN in Fig. 902, Plate 2. This illustrates a portion of the vortex revolving wheel, and the form of the veins, some of which do not extend to the central orifice. The object in so making them is that they may not too much fill up the contracted part of the passages, and thus impede the flow of the

The wheel is constructed either of steel or of rolled brass (the latter for small sizes), and as the vanes can thus be made very much thinner than of cast metal, their number can be increased, and perfect accuracy in the curvature secured. Hence the water enters the wheel with less interruption, and passes through more exactly in the direction intended than is the case where the vanes are of greater thickness, and fewer in number.

These vanes are fixed on each side of a steel or brass plate, having a boss in the centre to secure it upon the shaft, and discs or covers, in which are left circular openings through which the water passes after it has done its work: thus half the water is discharged on each side of the wheel as at VORTEX and WELL.

Here it will be just as well to compare the double and single vortex wheel; this is clearly shown at WHEELS, Fig. 902, Plate 3.

The essential difference between the single and double vortex wheel turbines is, that in the former the water is discharged from one side of the wheel only, the wheel of the single vortex being, in fact, half of that of the double, the centre plate of the latter forming the top cover of the former. The vortex guide blades direct the water on to the single wheel in precisely the same manner as they do in the double vortex.

This single vortex turbine is very well suited to medium and low falls, as shown at FIXED SINGLE VORTEX, Fig. 902, Plate 3, where a considerable body of water is to be dealt with, and where it is desirable to have the turbine left dry when the head of the water is shut off; and as the water is only discharged below the wheel, part of the fall may be utilised by a drag or suction pipe.

From what has been written on the development of the Gilkes' vortex turbine, it will be seen at a glance that it is one of the most useful machines for driving pumps, and the simple modes of fixing, as shown at FIXED SINGLE VORTEX, and also that shown at the FIXED DOUBLE VORTEX, render it as simple as possible; and any ordinary plumber should be able to fix it, or take it to pieces in cases of repairs.

I have given these two drawings, the former in part brickwork and part woodwork, to show the simplicity of the arrangement.

Here is simply a stream race from above right into the single wheel turbine, where the water flows through the vortex wheel to the tail water chamber below. Here, also, is shown the lever arrangement for bringing up the before-mentioned pivoted spindle of the wheel should it become worn.

I may also add that this spindle works upon lignum-vitæ, and lubricates itself by the water in which it is placed. Of course, the woodwork in front is partially cut away to show the fixing of the turbine, whilst the FIXED DOUBLE VORTEX turbine illustrates the water being brought from above, and through the strainer on top, and down a pipe into the double turbine, and needs no further description.

I may here remark that turbines are made to raise water from wells, and fixed after the manner of that shown at VORTEX and WELL, but the fan or turbine itself acts in the reverse way to that which I have already described. The turbine being then the user of the power instead of the giver, with the pulley L reversed, and it is usually driven by steam, or even it can be driven by a secondary turbine, in which case the streams in the pipe I J would be reversed.

The makers of this turbine lay it down that the efficiency of their turbine is found to be 75 per cent., but as it is not easy for anyone who has not had practice in this particular application of water power to judge with certainty how best to apply it, or what class of turbine to use, they recommend that, when possible, an engineer, who is accustomed to fixing turbines, should be asked to see the site. They lay especial stress on the point that the pipes bringing the water to the turbine should be kept large, so that the speed of the water shall not exceed 3ft. or 4ft. per second, as high speeds of flow involve considerable loss of working head. They also give the following example:—If a pipe a thousand feet long, with a hundred feet fall, is 7in. in diameter, and the quantity of water flowing through it be 100 cubic feet per minute, the speed is 6ft. per second. The pressure at the bottom of the pipe is 43lbs. to the square inch when no water is passing, but when 100 cubic feet per minute is flowing through, the pressure is reduced to 33½lbs. per square inch; this is equal to a loss of 22ft. head, and they would then recommend a 9in. pipe, if it was important to make the most use of the water power. The loss would then be under 7ft., or only 7 per cent. instead of 22 per cent.

They have also given the following rules for the guidance of those abroad requiring their turbines, in ascertaining the quantity of water required to produce a given power to their turbines under a given fall, or *vice versâ*.

The height of the fall in feet multiplied by the number of cubic feet of water available per minute, divided by 706, will give the actual *Brake* Horse-Power. The horse-power required multiplied by 706, and divided by the height of the fall in feet, will give the number of cubic feet of water required per minute. When the available quantity of water, and the requisite horse-power are determined, the horse-power multiplied by 706 and divided by the quantity of water in cubic feet per minute, will give the height of fall in feet that will be required to produce the horse-power.

One other important point is, when turbines are wanted in out of the way, mountainous, mining, or other districts, great difficulty is frequently experienced in the transit, owing to the weight of the various parts. To obviate this Messrs. Gilkes & Co. make large turbines in parts, not exceeding for the heaviest piece 300lbs., so that each piece can be carried separately on the back of a horse, camel, or mule. The cost of transport over rough mountains, &c., is thus very much reduced; but it would be well if the workman or engineer stated the largest weight that could be carried.

Fire Engines, Garden Pumps, &c.

The Fire Engine appears to be of very remote date. No doubt it was used by the Babylonians and ancient Romans, for we read of "The hydraulic engines of Ganymede nearly ruining Cæsar and his soldiers at Alexandria." And as a fact well recorded, Apollodorus or Viteuvius employed forcing pumps as fire engines (see the *Spiritalia* of Heron). This very rare and exceedingly old and interesting work contains an account and an illustration of an Egyptian fire engine made in the second century before the Christian era, not so very much unlike that shown at Fig. 908, except that the Egyptian engine does not run upon wheels, the principle and the mode of working being exactly that of Fig. 908, with double lever, valves and air chamber, but without any hose. I will now give you a description of those made at the present day.

FIRE-ENGINE PUMPS.

Every plumber, and other intelligent workman, should have a thorough knowledge of rough-built fire-engine pumps, and after what has been said about the preceding pumps, especially upon Figs. 852 and 854, this class of pump will be readily understood. I shall therefore only explain and illustrate a few of the best-worked pumps or fire-engines that are, or should be, kept ready for service at every farmhouse, mill, builder's yard, or mansion. We will begin with an illustration of a very simply made hand plunger pump, Fig. 903. It will be seen that this double

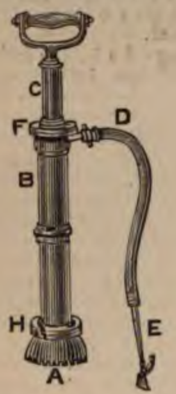


Fig. 903.

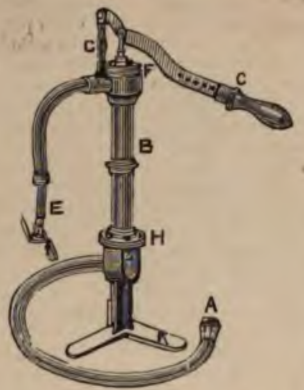


Fig. 903A.

action pump is made to stand in a pail, tub, or otherwise, whilst the right or left hand holds the hose, the other is engaged in pumping. The water passes under the *lead weighted* strainer A (which is sometimes fixed into a tank), and up into the barrel B, which forms a kind of air-chamber as well as barrel. This kind of pump, although not this design, can be had from Messrs. Hayward Tyler & Co. The method of repairing this pump is by unscrewing the flanges and releathering the valves or grinding them in. Fig. 903A is a similar kind of force-pump, but fixed upon a stand

Fig. 904.

Fig. 905.

having a lever and suction hose to place into a pail or otherwise. Fig. 904 is in principle made after the style of the ordinary plunge-pump, as illustrated at Fig. 840. It throws water into the tube Q, which acts as an air-chamber, and from there to the branch or nozzle at E. (For accounts of nozzles, see Nozzles.) This pump is generally fixed within a tank, like that shown at Fig. 906, as is also Fig. 905, which is, as far as regards the action of the pump, exactly the same as Fig. 904, the only difference being that the water in Fig. 905 comes off the top with universal joints instead of hose, whilst in the former, Fig. 904, it comes off at the side, and through a hose.

Barrow Pump.

Fig. 907 is an ordinary cottage or other pump, with air vessel and hose to fit nozzle. (See Figs. 840, 844, 854, &c., &c., all of which may be simply fixed upon a frame running on two wheels.) Here is one of the cheapest, most useful, and effective fire-engines that it is possible to make, and should be *found ready for use at all times* on every farm throughout the country, and the farm labourers taught to work it, say, once a month, and keep it in working order. A second leather suction or valve should always be with a spanner tied on to the side of the barrow, and a dozen of leather or other buckets filled with water always tied upon the shafts or handles of the barrow ready for instant use. Of course, in the winter time, when frost is about, the barrow should be kept dry. Turn to the pump table and let us see what quantity of water can be thrown, say, 20ft.

Fig. 906.

high in one hour, when the pump is worked by one man. A 5in. pump at a 9in. stroke 25 per minute, will throw 959 gallons. Now turn to Fig. 908. Here is a very simple but good and exceedingly powerful fire-engine of the class of the 18th century, and formerly kept in cathedrals or in old parish churches, and at times by the town crier in some out of the way place. This engine is fixed upon a frame to run on four wheels. D is the suction which screws on the bottom or tail of the suction valve. The water is then drawn to the barrel

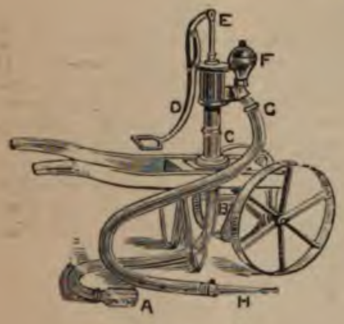


FIG. 907.

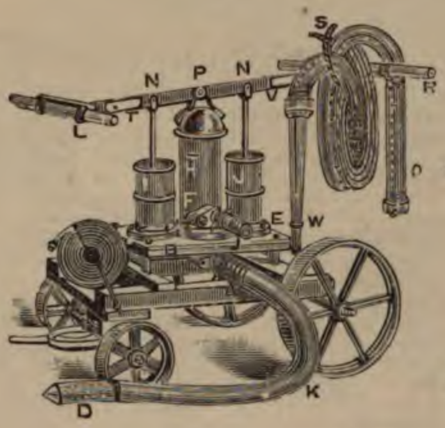


FIG. 908.

I or J with a plunger as shown at B, D, A, Fig. 840. It is then forced from the barrel through a valve, and into the air chamber H, Fig. 908, and from thence into the hose and through the branch. Here the lever, N, P, N, is supported by the fulcrum on the top of the air chamber, and can be worked by four or six men on each end of the lever, say five—that is, five men to each pump, and the height that the water has to be lifted is, say, 25ft. Here we could work an 8in. pump, and have power to spare. Assuming that the leverage is six to one, and twenty-five strokes per minute of 9in. stroke, we shall get about 2,454 gallons twice, or 4,908 gallons per hour out of this little engine, and if only to be raised half the height, we could get double this quantity with the same amount of labour, allowing plenty for friction, &c.

Important.—Be sure to have plenty of suction and other hose, and it should be always kept in good working order. (See instructions for Hose.)

Before we go any further on this engine, it will be as well to describe Newsham's, of Cloth Fair, London, interesting trials, which began about the year 1710. His first patent dates 1721, No. 439, and one of his engines can be seen at the Patent Museum, South Kensington. The working arrangement of his 1725 patent was with a segment and levers. Some of his engines were also fitted with foot treadles, and the engine wheels were generally made out of solid blocks of wood, rather low, and when such engines were required to go any distance they were mounted on trollies.

Newsham had a competitor, one Fowke, of Wapping, London. Fowke's engine worked without a rack and wheel or chain, and consequently was more like the diagram Fig. 908; but Fowke's machine was not up to the size, strength, and other points, necessary to produce the best results in throwing water jets, and it appears from the *Universal Magazine* of 1726, the *Daily Journal*, and the *Daily Post*, that these rivals made bets as to whose engine could give the best results. Fowke challenged Newsham to play his engine against him at Bridewell Hospital, in the presence of the Earl of Scarsdale, Lord Craven, Lord Gower, and the Governors, when Alderman Parson gave out that Newsham's engine carried a much closer stream and several yards further distance.

However, Fowke again challenged a wager. Newsham proposed to play into a back or vessel (which he never did before that day), and they that could play the greatest quantity at the greatest distance were to win. This was in every way agreeable to the memorandum before agreed to, which was refused, and left to the proper judges to decide, but this did not seem agreeable to Fowke's party. Newsham replied, "That he did not see any occasion to trouble their friends, when he had proposed a way whereby an old woman might be a judge," and to settle the matter, challenged Fowke to play his, Newsham's engine, against that of Fowke's over the Grasshopper at the Royal Exchange. Now the Grasshopper on the Royal Exchange (the old building) was 165ft. high. This Newsham did, which seemed to settle for ever the question Newsham *versus* Fowke's Fire Engine.

On the right-hand side will be seen a similar worked engine, but with the handle made to work across the bed, and with a tank that may be supplied with buckets, &c.

Modern Manual Fire Engine.

FIG. 909.

This class of fire engine belongs to the 19th century, and is the pioneer of the steam fire engine. This manual engine has done good service, and has been brought to perfection by Messrs. Merryweather, who turn out large quantities, and have taken many gold and other medals for design and workmanship thereon

The "Squire" Fire Engine.

The boiler of this engine is generally arranged for burning coal, but for wood when necessary, which may be cut up by the engine itself, and steam may be raised to the working pressure in fifteen minutes. The engine (see Fig. 910) is so simple in construction that it may be worked by a farm labourer of ordinary intelligence. It may be quickly taken to farmsteads, or to neighbouring estates in case of fire.

DESCRIPTION.

The boiler is of Lowmoor iron, fitted with annular water casing surrounding the firebox, and provided with inclined and curved tubes, all opening at each end to the water space, thus presenting a large heating surface and ensuring perfect circulation. Steam can be raised to working pressure in *fifteen minutes* from time of lighting the fire, and is maintained easily and with great economy of fuel. It is provided with feed tank, fitted over bunker, arranged for taking supply from main pump, with ball

FIG. 910.

valve and copper feed connections complete; also fitted with safety valves, and all necessary fittings.

The pump is vertical, fitted to the frame in front of boiler, and driven by means of a loose lever and crank pin, and connecting rod working off crank shaft, arranged to be readily put in and out of gear by removing a bolt.

FIG. 911.

Pump is of gun-metal, and has an improved double-acting arrangement, by which a continuous flow of water is steadily maintained, and is so arranged as to be easily accessible for cleaning and examination. It is capable of delivering 120 *gallons* per minute, and is fitted with capacious polished copper suction and delivery air vessels and all necessary fittings.

The engine is fitted with a crank shaft and turned flywheel, so that a belt can be put on to drive machinery when the pump is out of gear. It has a single cylinder, and is fitted together with steel rods and bolts. An efficient governor is also provided.

The engine and boiler are fitted on a strong iron frame, stayed with cross stretchers, and provided with bunker in front for carrying hose, tools, &c., all mounted on horizontal steel springs in front and rear, with wrought iron forecarriage and high wood spoke wheels.

At the present moment London is considered to be well supplied with first-class fire engines, capable of throwing tons of water per minute to the highest story of any private dwelling, and the design of these engines surpasses any in the world; in fact, our engines are supplied to all other countries, which will give my readers a general idea of what we are doing in the 19th century.

Refer to diagram, Fig. 911. Here we have five views of the work of the "Squire" fire engine, which needs no further explanation to the practical plumber; but for the information of the curious, I will say that the top lot is supposed to be engaged pumping water to supply a mansion when the water supply to the water-wheel B is insufficient during times of drought, &c.

The second part of our picture illustrates the "Squire" engine where it is busily driving at C the gear of a deep well pump. It can also be employed to drive a centrifugal pump, and will in this way lift 600 gallons per minute 12ft. high, and is thus suitable for draining or irrigating purposes. It is also engaged at C driving a dynamo, grinding electricity, and, as may be seen above at D, where it is rattling round a circular saw, or instead of a circular saw it may be employed to drive a thrashing machine, or a chaff cutting or turnip chopping machine; in fact, the machine can be used for scores of purposes upon a farm, even from dragging a plough to the watering or swilling down of trees, plants, irrigation, emptying ponds and draining, &c., and what can be a more important machine than that in which it is engaged on at the last part of our diagram, where it is using its utmost strength in its natural capacity. I need not here go into the mechanical details of engineers' work, as the plumber who *may* be called in to undertake such repairs, &c., should engage qualified workmen for the job, and he should be very chary about meddling with such high-class machines, for by his interference with such, unless he is well versed in mechanics, and is capable of properly working and otherwise handling, say, a metal turning lathe and metal planing machine, I say it would serve him right if he came to grief over such foolhardiness; for the engines and pumps of these machines are fitted with such great nicety that even a turn of a screw (unless it be a stuffing or packing nut, and sometimes then) may cause undue looseness or additional friction, which would altogether interfere with its working. Of course, I am aware that we have many English plumbers (such as Mr. James Pullen, junior) who are very fair all-round engineers and fitters; in fact, in my own workshop, I have trained one to do all sorts of fitting work in connection with the making of my lead trap, and other high-class moulds, and lead trap hydraulic presses; and this individual is well able and often does work the lathe and planing machine. But even these men would look twice before they undertook to pull to pieces, or otherwise meddle with, a high-class steam fire engine.

Fire Engine Hose Nozzles.

BRANCH AND NOZZLE.

HOLLOW JET NOZZLE.

FAN SPREADER.

STAR KNIFE SPREADER.

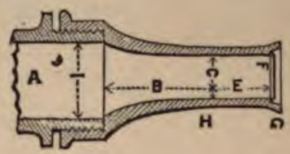


FIG. 912.

The Branch and Nozzles are a most important part of the fire extinguishing apparatus. It should be made to an exact form, well-proportioned, and according to the height and size of jet, and the available pressure behind it.

According to the ordinary practice, a stream after passing through a hose of, say, $2\frac{1}{2}$in. diameter is reduced to about $1\frac{1}{2}$in. by the BRANCH and NOZZLE and at A, Fig. 912, and the nozzle H carries this reduction yet further to any size necessary for the work, or to get the best possible stream by reducing as at B (to a certain limit) the size of the nozzle. It should be done with a gradual, easy, and smooth curve, till it arrives at about C, Fig. 912, then with the walls of the branch pipe from A to about D, straight or parallel (some makers make this parallel part as long as the diameter of the outlet of the nozzle only), when it should *slightly and gradually* expand itself $\frac{1}{16}$th of its diameter to about F, leaving a little lip as at F, with an external lip or projection, not merely for the protection of the bore against indentations, but as a protection and to throw off any induced current of air caused by the issuing stream to trail in at the back of the stream as it leaves the nozzle.

This is rather important, as all jet streams, more or less, are interfered with by this induced current of air, and which tends to create a partial vacuum, and to drag the tail end of the stream. With regard to the $\frac{1}{16}$th part expanding of the nozzle, this is not paid much attention to by fire engine makers, they preferring to keep the nozzle from C to F perfectly parallel, in order to compact the stream and prevent spreading.

The shape of these nozzles has been pretty well exhausted, but for one of the most reliable shapes, I refer you to the practical experiments of Mr. M. Merryweather, about the year 1835, since which time few alterations of any value have been made.

Mr. M. Merryweather's successor says, "As English fire brigades use hose of a maximum diameter of $2\frac{3}{4}$ins., and the branch pipes in use are only about $1\frac{1}{2}$ins. diameter at the top, it follows that nozzles of a large size have necessarily to be constructed with due regard to these facts, and cannot be theoretically accurate in regard to form. The whole of the reduction has to take place from $1\frac{1}{2}$ins.

"If, for instance, the size of the bore be $1\frac{1}{4}$in., the reduction of area is only slight, whereas if the bore is $\frac{1}{2}$in., the reduction is to $\frac{1}{5}$th of the area of the branch pipe top. Manifestly in two nozzles of about the same length the reduction cannot be carried out with, theoretically, equal satisfactory results."

It cannot be doubted that large nozzles as well as small ones are of the best shape for fire brigade purposes, due regard being considered to the conditions mentioned above, viz., fixed sizes of branch pipe tops; and this difficulty could only be got over by carrying different nozzles and hose of larger diameters, which is inadvisable and cumbersome.

Some of these nozzles, however, are made from $1\frac{3}{4}$in. to $2\frac{1}{4}$in. in bore, and for a single stream only, and the employment of a $1\frac{1}{2}$in branch pipe, would be useless, and larger sizes must be used with larger couplings and hose.

Going back to the question of the nozzle shape, it must be always borne in mind that the reduction should be gradual from the hose to the cylindrical part of the nozzle, and the coned part should not finish abruptly or with a square edge, and the length of the cylindrical part should be at least one diameter long, for this reason: that the stream may be shaped or pressed perfectly smooth and round and into a solid stream, which cannot easily break up into a spray, as does the stream issuing from a tapered jet, which latter begins to break up as soon as it reaches the atmosphere, the external walls of water having been agitated by undue friction caused by the sharp edge of the cone, and these external walls are, so to speak, slow to that in the internal, and in a complete spinning condition.

Water Pressure for Hose Nozzles.

The pressure required necessary to throw effective streams to different distances will be found of importance, and the following will give an approximate result for different size nozzles, assuming the pressure to be direct off the pump into the hose, and a free way 2½in. smooth hose used, without a lot of bends, and 100ft. in length.

We will take a 1⅜in., the medium sized nozzle, as the one preferred, to commence with. If off a hydrant the projection will be a little greater.

1⅜in. NOZZLE.

Vertical Height in feet	70	80	90	100
Horizontal Distance in feet ...	65	75	85	95
Gallons per minute	300	337	400	450
Pressure on Nozzle, lbs. per sq. inch	40	50	70	90
Pressure on Pump, lbs. per sq. inch	110	135	190	240

1¼in. NOZZLE.

Vertical Height in feet	65	85	95	100
Horizontal Distance in feet ...	60	75	85	100
Gallons per minute...	245	300	350	390
Pressure on Nozzle, lbs. per sq. inch	40	60	80	100
Pressure on Pump, lbs. per sq. inch	85	130	170	210

1⅛in. NOZZLE.

Vertical Height in feet	65	80	90	100
Horizontal Distance in feet ...	60	70	80	90
Gallons per minute...	200	240	280	310
Pressure on Nozzle, lbs. per sq. inch	40	60	80	100
Pressure on Pump, lbs. per sq. inch	70	110	140	180

1in. NOZZLE.

Vertical Height in feet	70	80	90	95
Horizontal Distance in feet ...	60	70	80	85
Gallons per minute...	180	200	230	240
Pressure on Nozzle, lbs. per sq. inch	50	70	90	100
Pressure on Pump, lbs. per sq. inch	75	100	130	145

⅞in. NOZZLE.

Vertical Height in feet	60	75	85	90
Horizontal Distance in feet ...	45	58	68	75
Gallons per minute...	120	140	165	185
Pressure on Nozzle, lbs. per sq. inch	40	60	80	100
Pressure on Pump, lbs. per sq. inch	50	75	100	125

¾in NOZZLE.

Vertical Height in feet	60	70	80	85
Horizontal Distance in feet ...	45	55	60	65
Gallons per minute...	85	105	120	135
Pressure on Nozzle, lbs. per sq. inch	40	60	80	100
Pressure on Pump, lbs. per sq. inch	45	65	90	120

Spreading Nozzles.

These are numerous. The simplest is the FAN SPREADER, the drawing of which explains itself.

The Star KNIFE Spreader is another form, which also explains itself.

The Cone Spreader.

Sometimes an inverted Cone is used instead of the [illegible] in the Cone Spreader.

The Ball Spreader.

This is a spreader much about the same shape as the Star KNIFE Spreader, but having a smooth hard india-rubber or other ball (similar to the basket jet in Fountain Jets), which, owing to the shape of the nozzle, the water tends, so to speak, to open as does the wind from a trumpet, and this clinging of the water to the sides of the bell cone naturally tends to split up the stream in the centre, putting the surrounding air, both inside and outside, into rapid motion, and thus tends to form a partial vacuum in the centre of the inside stream, and to keep the ball driving towards the centre. (See India Rubber and other balls, steam jets, &c.)

Ball Speed to create a Vacuum through Air.

Of course, I am well aware of how fast a body must travel through the air to create a vacuum behind it. Theoretically speaking, the velocity would have to be about 918 miles per hour, but, practically speaking, it is 650 miles. The theoretical velocity of the air that will flow into a vacuum, if wholly unobstructed, is 1347·4ft. per second, whilst in practice it is only 952·61ft. It will be plain that the ball, driving towards the centre of the issuing stream (and once the ball being there), the internal walls of the stream (at the periphery of the ball) increase, and as the balls spin so the water lashes in at the back of the ball at a high speed, and so keeps it driving against the centre point, which has the least resistance, whilst, owing to the water backing on the back part of the ball, it becomes scattered, and, as such, the whole outer stream becomes agitated, and a spray is the result.

Fire Hose.

Too much attention cannot be paid to fire hose, for, if allowed to be run over or otherwise become injured, the evil may not be discovered just at the time, and when this important part is required, it is then there is the falling off, and many a building has been totally wrecked through this unforeseen catastrophe.

Again, it is not only actual violence brought about by the wheel tyres of the vehicle, but there are other reasons for injury, one is that the hose is very often not properly cared for after its being in use, often being thrown into the bunker or into some out-of-the-way place, where it lies for months together with water therein, instead of being always nicely rolled up to be taken to its station or other destination, and there properly hung by one end of the coupling to drain out, and otherwise properly looked after; and care should be taken that it does not become hard and perished for the want of a little oiling, and other valuable, though small, attentions.

There is another way in which hose often becomes injured, by putting excessive pressure thereon by having an intermediate cock or valve on the outlet end. The pressure should be governed by a valve, as at E, Fig. 1,067, or as at Fig. 1,076, or if the engine be used with a dam, then the pressure should be regulated on the outlet side of the pump; in fact, under no conditions should there be a cock between the nozzle and the hose, when under very high pressure.

Rotary Pumps. (*Also see Turbines.*)

Of these there are a great variety (see Fig. 913). Here, at A, it will be observed that the inner scolloped wheel contains four rollers, which play between the slots in the scolloped wheel and the periphery of the cylindrical chamber. The action is as follows: By giving motion to

A. B.

Fig. 913.

C.

Fig. 913.

Fig. 914.

the handle B, or to the wheel C, the scolloped roller wheel will revolve, thereby carrying the rollers, which, coming past the suction port-hole, cause a partial vacuum and forces the water up the rising main. These pumps may be varied to suit circumstances, and as their name is legion, and the plumber having little to do with them, it is not necessary to further explain in this work, as he should now be able to think for himself about pump work.

Chain Pumps. (See Fig. 918.)

There are a variety of chain pumps. The principle is nearly that of the rag wheel reversed. By turning back to Fig. 900, and imagining the bucket F, C, H to be dipping into the water, and the wheel K to make progress from L to M, it will be plain that such an apparatus must bring the water from below in the buckets and discharge themselves into a suitable trough at the top, as at Fig. 918.

These pumps are very much used for bringing water out of wet excavations, for sewers, deep cuttings, and such-like places. They are exceedingly handy in places where shingles and such-like, even to brickbats, abound.

Another kind of chain pump is to place discs on an endless chain, the upward portion of which passes through an upright tube.

Pumps for Testing Purposes.

It often happens that a plumber requires to test his valves or cocks for soundness. My work on pumps will, therefore, not be complete without reference to the same. Such an apparatus is shown at Fig. 914, and by careful examination you will see that almost any pressure can be put on to the valve or cock, which may be fixed as shown

at the wheel valve by a screw, which keeps the valve down upon a suitable seating of leather, through which passes the pipe from the pump. After what I have said on pumps, such a one as is shown in this Fig. will be clearly understood, as in reality its action is the same as at Fig 903; but this proving or testing pump, Fig. 914, has a piston or plunger of very small diameter, even as small as, say, a square half inch. Now, supposing such an apparatus to be in your possession, and it is required to know what pressure you can put per square inch upon the cock. Say the lever is 5ft., the fulcrum 2in., here we have a multiplication of thirty times. Now, supposing 100 lbs. weight to be put on the end of the lever, here you have thirty times 100 lbs. (3,000 lbs.) pressing upon the piston or plunger, which, as before said, is half an inch square area, and, as there are four half inches in the one square inch, it will be plain that you will have per square inch pressure to multiply the thirty 100 lbs. by four, which equals one hundred and twenty 100 lbs., or say 12,000 lbs. to the square inch. This apparatus is supplied with water from the cistern above, or in any other way.

Boiler and Tank Testers.

This class of tester is shown at Fig. 915, and will be readily understood.

FIG. 915.

Both of the above pumps may be had from Messrs. Bailey.

Hydraulic Lifts and Presses.

You have seen what enormous pressure can be obtained by the two foregoing diagrams. We will now see what can be done by the hydraulic press, which, for simplicity's sake, I have designed Fig. 916. Here, at C, B, L, K, is the force pump, the piston of which is, say, for simple calculation's sake, one square inch, the leverage of handle, multiplied by six, say, 672 lbs. Now, say the ram, N, to be equal to 144 square inches, this, multiplied by 672, gives a lift [illegible] lbs., or over 43 tons lift. Here, in this simple [illegible] be seen what enormous power can be obtained [illegible] sure.

The class [illegible] at UNION VALVE.

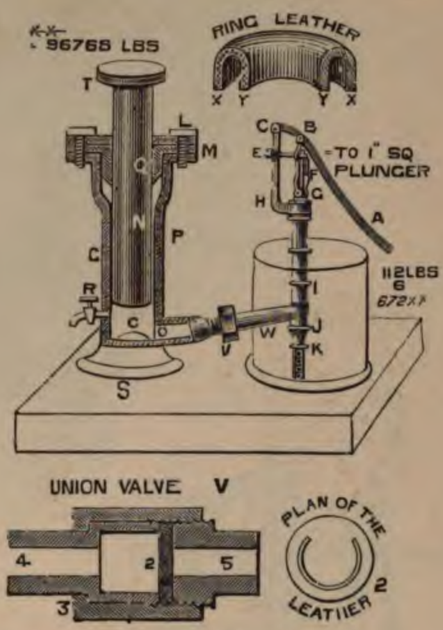


FIG. 916.

Cupping Leathers for Pumps.

You may require to make a cup leather for the bucket B, Fig. 917. This you can do as shown at Fig. 917. R is simply an iron ring about the size and depth you require as a cup leather, L is the leather, K the plug, the same size as the ring, bar the thicknesses of the leather, S a

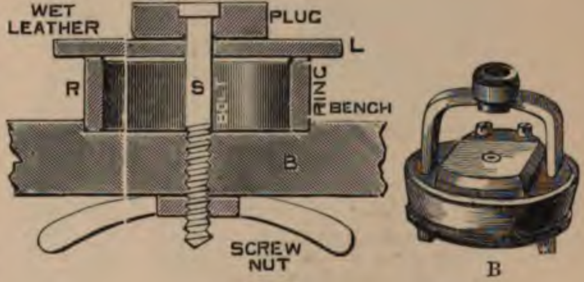


FIG. 917.

screw, actuated by a nut underneath, and working through a hole in the bench or otherwise.

Having got the leather the right substance and size, well soak it, and fix it as shown, and screw, or otherwise press it into the socket, and let it stand till dry; then trim off the edges, and you have the cup leather.

These cup leathers are usually cupped up with the lathe, R being a chuck, K a plug to force the leather disc into the chuck with the back centre, then the surplus leather can be trimmed off with a cutting tool whilst the lathe revolves, but, as everyone has not a lathe, the Fig. [illegible] given.

THE NORA.

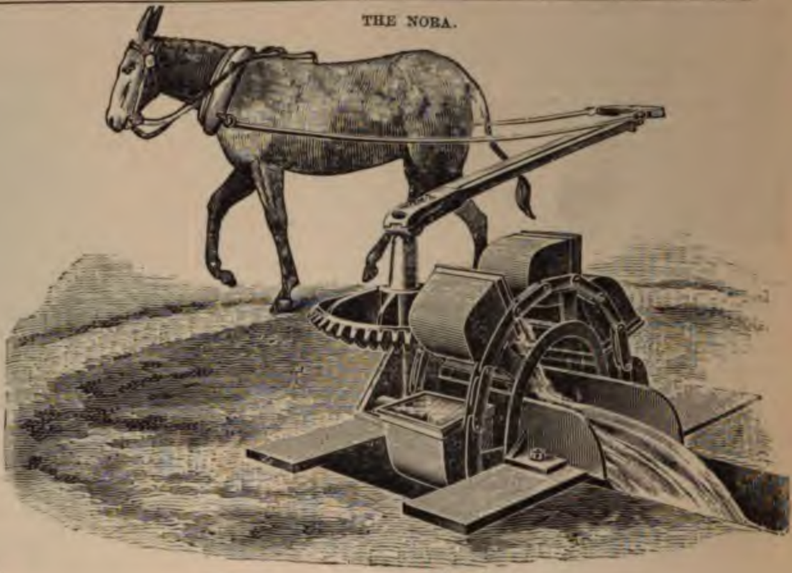


FIG. 918

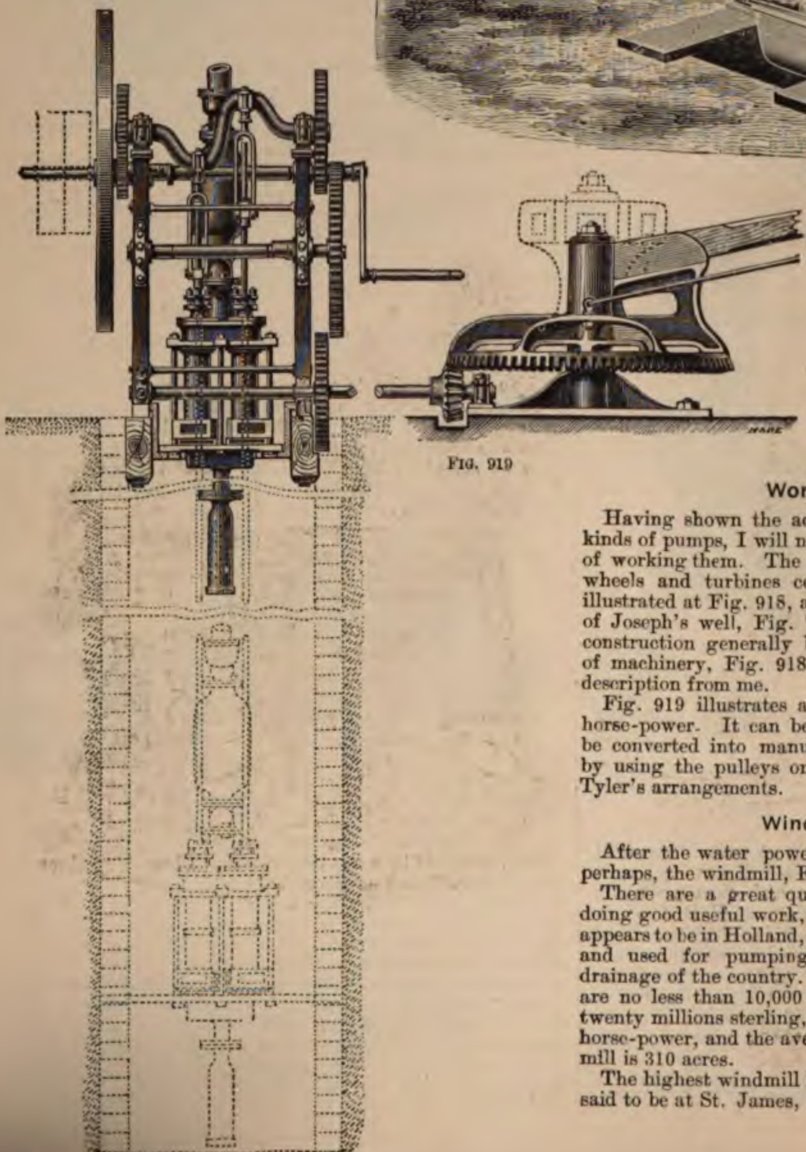


FIG. 919

Working Pumps.

Having shown the action and general make of various kinds of pumps, I will now proceed to explain a few modes of working them. The first handy motor after the water wheels and turbines comes horse-power. This is well illustrated at Fig. 918, and is much about the same as that of Joseph's well, Fig. 770, enlarged and improved in the construction generally by Messrs. Tyler, and such a piece of machinery, Fig. 918, is too plain to require further description from me.

Fig. 919 illustrates a deep well pump, also worked by horse-power. It can be used for shallow wells, and may be converted into manual or steam, or by water power, by using the pulleys on the left. This is one of Messrs. Tyler's arrangements.

Windmill Pumps.

After the water power, the cheapest pump motor is, perhaps, the windmill, Fig. 920.

There are a great quantity to be found about England, doing good useful work, but the home of windmill pumps appears to be in Holland, and is generally fixed on low levels, and used for pumping water in connection with the drainage of the country. It is said that in Holland, there are no less than 10,000 windmills, representing in value twenty millions sterling, with an aggregate force of 52,200 horse-power, and the average area drained by each windmill is 310 acres.

The highest windmill in the world for pumping water is said to be at St. James, Long Island. It is 150ft. high in

the tower. The windmill itself is of the wheel type, 22½ft. in diameter, and forces water 2,000 yards horizontally to a height of 223ft. into a 65,000 gallon reservoir—two days' work. This windmill has a foundation 46ft. square. The framework rests upon eight piers, one at each corner, and one under the centre of each side. For the first 125ft. of the tower, the framing consists of heavy yellow pine, having 6in. square struts at each corner post, and 6in. by 10in. for the centre columns, all braced together by heavy diagonal timbers. There is about six tons of ironwork in

Fig. 920.

the framework alone. There are a number of flights or stories from 12ft. to 15ft. high, connected by a staircase. There is an easy access to the top, which is 20ft. square.

This is one of the best windmills for ordinary pump work, suitable for raising water 150ft. high above the level of the water in the well. It is suitable for water supply to mansions, estates, farms, &c. ; also applicable for drainage.

The pumps can be placed in the supports, or down the well, but always within the draught of the water.

The class of pump to be used should be of the continuous primed class.

The general height from ground level to centre of sail, is 16ft. to 50ft.

A No. 1, with 3in. pump, and 16ft. to the centre of sail from ground, with an average eight days' work, and a breeze of fourteen miles per hour, should throw 250 gallons 100ft. high per hour.

A No. 2, with a 3in. pump, and 17ft. centre from the ground, will throw 250 gallons 150ft. high per hour.

A No. 2, with a 4in. pump, will raise 400 gallons 100ft. high per hour.

Storage tanks should have a capacity of at least six days' consumption.

Messrs. Hayward Tyler will guarantee this work.

These windmills have automatic safety reefing, self-facing the wind, and hand regulating apparatus.

I may add that often windmill pumps are also fitted with horse gear to work the pump when the wind is not sufficient; also they are fitted for hand work, as shown.

Electric Pumps.

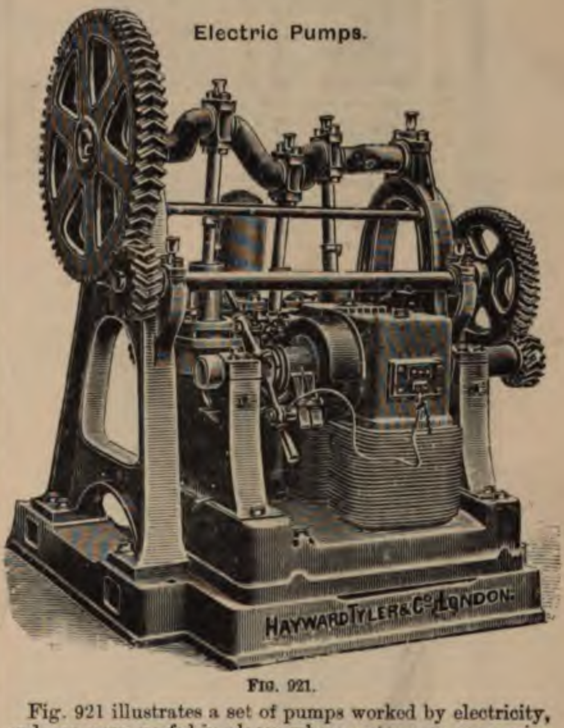


Fig. 921.

Fig. 921 illustrates a set of pumps worked by electricity, and are very useful in places where a steam or gas engine cannot be employed.

If you have the electric wire necessary for lighting purposes running by your house or premises, all you want is a connection, and you have what power you require whenever you like. Here is another strong move by Messrs. Hayward Tyler.

Steam Engine Pumps.

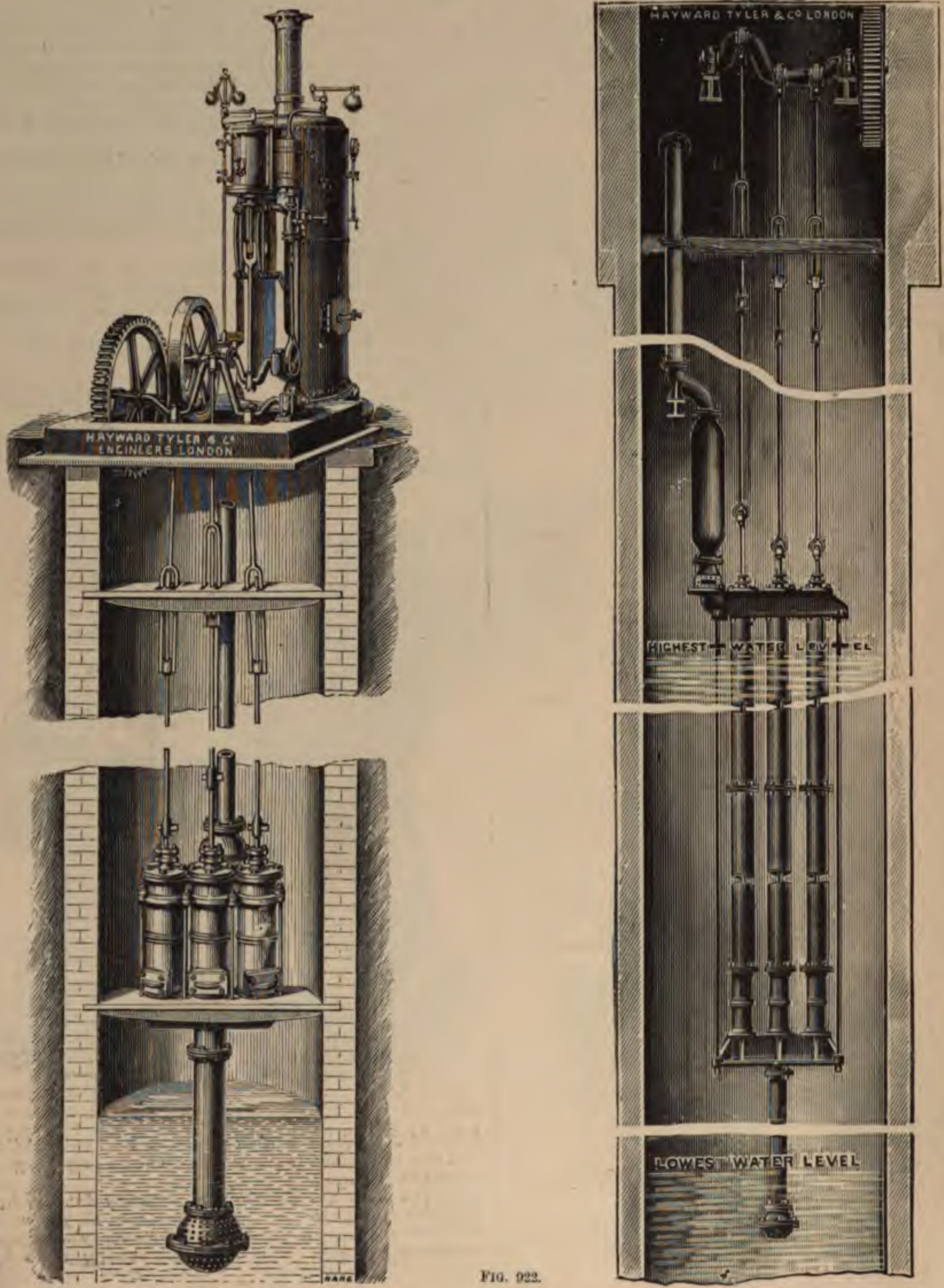


FIG. 922.

Stationary Steam Engine Driven Pumps.

Fig. 922 is an illustration of a set of three throw pumps, showing the coupling arrangements of Messrs. Tyler. There is, with this arrangement, a flywheel, which keeps the work steady and regular, no matter whether you work one, two, or three barrels at one time. The barrels, as can be seen, are bolted with long rods or bolts down upon the stage and under part of the pumps by suitable lugs near the top of the barrels.

On the right-hand side of Fig. 922 is to be seen a decided improvement in deep well pumps, designed to meet the requirements of fluctuating heights of water in wells, summer or winter. In this part of the diagram you will see the working barrels slung below the stage; you will also see the height of the water at HIGHEST WATER LEVEL, and, as is also shown, the lowest water level. This method of fixing pumps allows the plumber to put new cup leathers or valves when the pump barrels are below the water, and will be well understood and appreciated by the workman.

Pumping Station Engines.

THE WORTHINGTON STEAM PUMP.

The valve motion is the prominent and distinguishing peculiarity of the Worthington pump. To it it owes its complete exemption from noise or concussive action. Two steam pumps (see section and elevation, Figs. 923 and 923A) are placed side by side forming one machine, and so combined as to act reciprocally upon the steam valves of each other. The one piston acts to give steam to the other after which it finishes its own stroke, and waits for its valve to be acted upon before it can renew its motion. This pause allows all the water valves to seat quietly, and removes everything like harshness of motion.

As one or the other of the steam valves must be always open, there can be no dead point. The pump is, therefore, always ready to start when the steam is admitted, and is managed by the simple opening and shutting of the throttle valve.

In its application to steam pumps for ordinary service, as well as to water works engines of largest class, a combination of reliability, with economy in first cost, and in running expenses, is attained, not realised by any other type of pumping machinery.

It is claimed that this machine is distinguished for great simplicity and strength of construction, having few moving parts, with no harsh motions, and not subject to fracture or other derangement.

In the arrangement of the Worthington steam pump, special care has been taken to have the parts easily accessible for inspection or repairs. All the moving pieces being made to gauge, they can be readily renewed.

Added to its durability, the smooth and noiseless action of the Worthington steam pump makes it preferable on many important services, where the jar of a single cylinder or crank and flywheel pumps would be objectionable or destructive.

The successful application of a pump depends much upon its proper selection from among many patterns differing from each other in size, proportion, material, and general arrangement.

The following are the essential points to study when about to adopt this important class of pump:—

1st.—To what service is it to be applied?

2nd.—The quality of the liquid to be pumped, whether salt, fresh, acid, clear or gritty; and whether it is to be pumped cold or hot. When hot water is to be pumped, the difficulty of lifting it by suction increases with the temperature. It should therefore be arranged to flow into the pump chamber, if so hot as to vaporise when the pressure of the atmosphere is removed.

3rd.—To what *height* is the water to be lifted by *suction*, and what is the length and diameter of the suction and discharge pipes?

4th.—Of what material is the suction pipe, and what is its general arrangement as regards other pipes leading into it, &c.?

5th.—To what height, or against what pressure is the water to be pumped?

6th.—What is the greatest quantity of water needed per hour?

7th.—What pressure of steam is used?

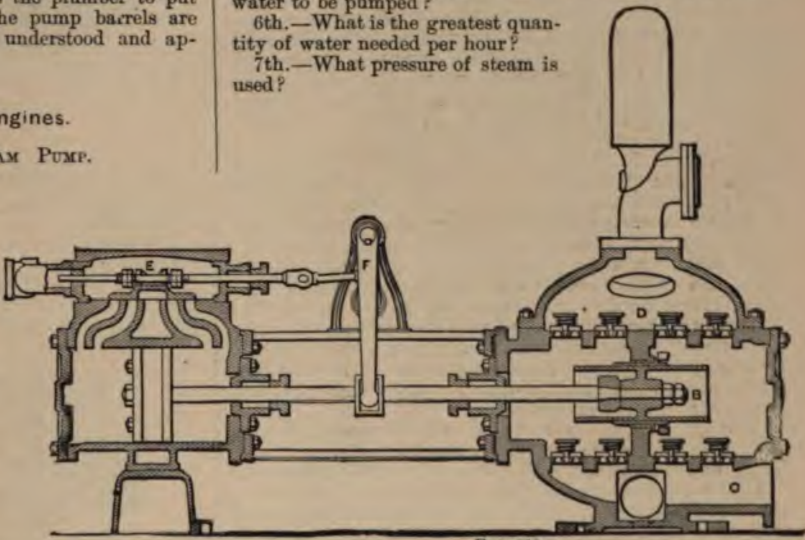


FIG. 923.

When calculating the capacity of the Worthington pump, remember that it has two double-acting plungers, and, therefore, four times that of a single-acting pump of the same size.

FIG. 923A.

The illustration, Fig. 923, is a sectional view of one side or half of a Worthington high pressure steam pump of ordinary construction. Its object is to exhibit the great simplicity of its interior arrangement, especially that pertaining to the steam valve.

This valve, as may be seen at E, is an ordinary slide valve, working upon a flat face over ports or openings. Its simplicity and durability, in contrast with any other form of steam valve, are well known. Although numerous attempts have been made to supersede it, it still maintains its place on locomotives and other forms of high pressure crank engines. No matter how long the engine may stand inactive, a slide valve will not rust or adhere to its seat, and is always ready to start when required. No water can collect in its cavities to produce trouble by freezing. In a word, it may be called the simplest and most reliable steam valve known to engineers.

In the Worthington engine the motion of this valve is produced by a vibrating arm, seen at F, which swings through the whole length of the stroke, with long and easy leverage. As the moving parts are always in contact, the blow inseparable from the tappet system is avoided. Even the motion of the well-known eccentric upon crank engines is not comparable to this for moderate friction and durability.

You should also direct your attention to the arrangement of the double-acting plunger, shown at B, which differs from all our previous pumps. Here the piston is more like a cylinder working through a deep metallic packing ring, bored to an accurate fit, being neither elastic nor adjustable. Both the ring and the plunger can be quickly taken out, and either refitted or exchanged for new ones at small cost; and if it be desired at any time to change the proportions between the steam pistons and pumps, a plunger of somewhat larger size, or decreased to any smaller diameter, can be readily substituted. As exact proportions between the power and work are always desirable, if not necessary, this is a very important advantage.

This system of renewal of the working parts has been proved by long experience to be the least expensive and most satisfactory for ordinary work. The plunger is located some inches above the suction valves, to form a subsiding chamber, into which any foreign substance may fall below the wearing surfaces. This enables it to work longer without renewal than the usual form of piston pump, especially in water containing grit or other solid material. The water enters the pump from the suction chamber C, through the suction valves, then passes partly around and partly by the end of the plunger, through the rising main valves, nearly in a straight course, into the delivery chamber D, thus traversing a very direct and ample water way. The bottom and top plates furnish a large area for the accommodation of the valves. These consist of several small discs of rubber, or other suitable material, easy to examine, and inexpensive to replace.

As before said, Fig. 923 only shows half of the machine, but, by examining the elevation, Fig. 923A, the whole, or apparent, two pumps and steam cylinders can be observed. I have fixed many of these pumps in chemical and other works, and the quantity of them supplied is almost, if not quite, a guarantee as to their performance and quality of workmanship; for when it is known that at the present moment the total daily capacity of the Worthington pumping engines on water work service is close on three trillion gallons, it is something to warrant one in saying that this company is one of, if not the first pump makers in the world. And it must not be lost sight of that these pumps are not only for ordinary water pumping, but are made for pumping air, acids, and for general chemical works work, and also for heavy hydraulic lifts, &c., and I have never known one that has not given general satisfaction.

This steam pump, Fig. 923B, is a splendid piece of mechanism, much used at large pumping stations. It is made by the Fire Appliance Company, to any magnitude, and is a good piece of hydraulic engineering.

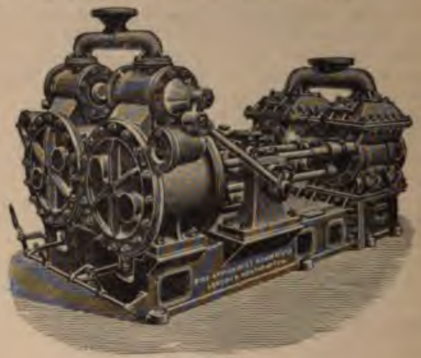


FIG. 923B.

Water Motors.

Fig. 923C illustrates a Worthington water motor of small size. The larger sizes differ considerably in general appearance.

These machines are designed to be driven by water pressure instead of steam. In their construction they do not differ materially from the ordinary Worthington steam pump, except that the driving cylinders are provided with ports and pistons suitable for water pressure.

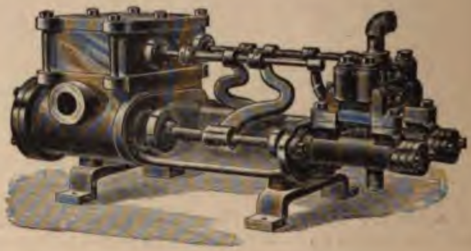


FIG. 923C.

They are extensively used in the service of supplying house tanks with water, where the pressure in the main street is not sufficient in itself to fill the tanks. In such cases a certain proportion of the water from the main is used to drive the motor and lift a smaller proportion to the tank.

They are constructed of proportions suitable for any conditions of service, and have been built of large size capable of supplying towns or cities with water. In the larger sizes the driving cylinder valves are balanced.

In designing motors for any given work, the following conditions should be known:—

1st.—The height to which the water is to be elevated, its quantity, and the size of connecting pipes.

2nd.—The pressure per square inch, or head in feet, under which the water to be used in driving the machine will enter the cylinders, and the quantity that can be utilised.

3rd.—Whether the same water that is to be used in driving the motor is to be pumped, or water from another source.

When these data are furnished, Worthington motors adapted for any service can be

List of Sizes of Water Motors.

Size.			Strokes per Minute, *ONE* Plunger.	Gallons per Minute, *BOTH* Plungers.	Sizes of Pipes.		
Steam Cylinders.	Water Cylinders.	Length of Stroke.			Cylinder Inlet.	Cylinder Outlet.	Discharge.
3 ×	1½ ×	4	60	3½	1½	1½	¾
4 ×	1¾ ×	4	60	3½	1½	1½	¾
3 ×	1⅞ ×	4	60	4¼	1½	1½	¾
4 ×	2¼ ×	4	60	8	1½	1½	¾
9 ×	2¾ ×	9	48	16	4½	4½	1¼
9 ×	4½ ×	9	48	60	4½	4½	2½
9 ×	5 ×	9	48	72	4½	4½	2½
17½ ×	4½ ×	12	40	65	8	8	2
17½ ×	7½ ×	12	40	180	8	8	4
17½ ×	12 ×	12	40	465	10	8	7

To designate the sizes, give the diameter of Power Cylinders and Pumping Cylinders, and length of Stroke; also see Injectors.

Useful Hints and Facts.

To be Committed to Memory.

One imperial gallon = 277·274 cubic inches.
One imperial gallon = ·16 cubic foot.
One imperial gallon = 10 lbs.
One cubic inch of water = ·03607 lb.
One cubic foot of water = 6·23 imperial gallons.
One cubic foot of water = ·557 cwt.
One pound of water = 27·72 cubic inches.
One pound of water = ·10 imperial gallon.
One cwt. of water = 1·8 cubic foot.
One ton of water = 35·9 cubic feet.
One ton of water = 224 imperial gallons.
A column of water 1ft. high has a pressure at base of ·434 lb. per square inch.
A pressure of 1 lb. per square inch = a column 2·31 feet high.

Frictional Loss in Pipes.

Approximate Flow per Minute.

A *straight* pipe 100ft. long will cut down the head and retard the flow as follows, *in pounds pressure*:—

Imperial Gallons.	Size of Pipes.							
	¾ in.	1 in.	1¼ in.	1½ in.	2 in.	3 in.	4 in.	5 in.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
4	3·3	·84	·31	·12	—	—	—	—
8	13	1·05	·47	·47	·12	—	—	—
12	28·7	6·98	2·38	·97	·27	—	—	—
16	50·4	12·30	4·07	1·66	·42	—	—	—
20	78	19	6·40	2·62	·67	·10	—	—
25	—	27·5	9·15	3·75	·91	·12	—	—
29	—	37	12·4	5·05	1·26	·14	—	—
33	—	48	16·1	6·52	1·60	·17	—	—
37	—	—	20·2	8·15	2·01	·27	—	—
41	—	—	24·9	10	2·44	·35	·09	—
62	—	—	56·1	22·40	5·32	·74	·21	—
83	—	—	—	39	9·46	1·31	·33	·05
103	—	—	—	48·1	14·9	1·99	·51	·07

Theoretical Water Pressure Table per Square Inch.

For those that cannot readily calculate, and for quick the following worked out table of the pressure on the square inch from 1 to 250 feet, and by reversing the order from lbs. to feet, can be seen at a glance.

Height of Column in feet.	lbs. pressure on bottom per sq. inch.	Height of Column in feet.	lbs. pressure on bottom per sq. inch.	Height of Column in feet.	lbs. pressure on bottom per sq. inch.	Height of Column in feet.	lbs. pressure on bottom per sq. inch.
1	0·43	64	27·72	127	55·01	190	82·30
2	0·86	65	28·15	128	55·44	191	82·73
3	1·30	66	28·58	129	55·88	192	83·17
4	1·73	67	29·02	130	56·31	193	83·60
5	2·16	68	29·45	131	56·74	194	84·03
6	2·59	69	29·88	132	57·18	195	84·47
7	3·03	70	30·32	133	57·61	196	84·90
8	3·46	71	30·75	134	58·04	197	85·33
9	3·89	72	31·18	135	58·48	198	85·76
10	4·33	73	31·62	136	58·91	199	86·20
11	4·76	74	32·05	137	59·34	200	86·63
12	5·20	75	32·48	138	59·77	201	87·07
13	5·63	76	32·92	139	60·21	202	87·50
14	6·06	77	33·35	140	60·64	203	87·93
15	6·49	78	33·78	141	61·07	204	88·36
16	6·93	79	34·21	142	61·51	205	88·80
17	7·36	80	34·65	143	61·94	206	89·23
18	7·79	81	35·08	144	62·37	207	89·66
19	8·22	82	35·52	145	62·81	208	90·10
20	8·66	83	35·95	146	63·24	209	90·53
21	9·09	84	36·39	147	63·67	210	90·96
22	9·53	85	36·82	148	64·10	211	91·39
23	9·96	86	37·25	149	64·54	212	91·83
24	10·39	87	37·68	150	64·97	213	92·26
25	10·82	88	38·12	151	65·49	214	92·69
26	11·26	89	38·55	152	65·84	215	93·13
27	11·69	90	39·98	153	66·27	216	93·56
28	12·12	91	39·42	154	66·70	217	93·99
29	12·55	92	39·85	155	67·14	218	94·43
30	12·99	93	40·28	156	67·57	219	94·86
31	13·42	94	40·72	157	68·00	220	95·30
32	13·86	95	41·15	158	68·43	221	95·73
33	14·29	96	41·58	159	68·87	222	96·16
34	14·72	97	42·01	160	69·31	223	96·60
35	15·16	98	42·45	161	69·74	224	97·03
36	15·59	99	42·88	162	70·17	225	97·46
37	16·02	100	43·31	163	70·61	226	97·90
38	16·45	101	43·75	164	71·04	227	98·35
39	16·89	102	44·18	165	71·47	228	98·76
40	17·32	103	44·61	166	71·91	229	99·20
41	17·75	104	45·05	167	72·34	230	99·63
42	18·19	105	45·48	168	72·77	231	100·06
43	18·62	106	45·91	169	73·20	232	100·49
44	19·05	107	46·34	170	73·64	233	100·93
45	19·49	108	46·78	171	74·07	234	101·36
46	19·92	109	47·21	172	74·50	235	101·79
47	20·35	110	47·64	173	74·94	236	102·23
48	20·79	111	48·08	174	75·37	237	102·66
49	21·22	112	48·51	175	75·80	238	103·09
50	21·65	113	48·94	176	76·23	239	103·53
51	22·09	114	49·38	177	76·67	240	103·96
52	22·52	115	49·81	178	77·10	241	104·39
53	22·95	116	50·24	179	77·53	242	104·83
54	23·39	117	50·68	180	77·97	243	105·26
55	23·82	118	51·11	181	78·40	244	105·69
56	24·26	119	51·54	182	78·84	245	106·13
57	24·69	120	51·98	183	79·27	246	106·56
58	25·12	121	52·41	184	79·70	247	106·99
59	25·55	122	52·84	185	80·14	248	107·43
60	25·99	123	53·28	186	80·57	249	107·86
61	26·42	124	53·71	187	81·00	250	108·29
62	26·85	125	54·15	188	81·43		
63	27·29	126	54·58	189	81·87		

Bends and Loss of Head.

The resistance offered by bends in channels or pipes to the flow of water is considerable, and there are many methods of calculating the loss, and the following is Beardmore's, amended:—

$$h = \frac{V^2 \times S^2 \times N \times \cdot 003}{\sqrt{\frac{d}{4}}}$$

h = head in inches, to overcome resistance.

V = velocity in inches, per second.

S = line of angle.

N = number of bends.

$\frac{d}{4}$ = hydraulic mean depth of pipe.

Loss of head caused by bends should be in your calculations taken or deducted from the head, and the calculations then made with the reduced head.

Tables and Questions on Pipes, Wells, Pumps, Power, &c.

Now that we have gone through the foregoing preparatory work, which has given my readers a general insight into the science and art of the pump, I will give, before proceeding further, a few tables and rules suitable for plumbers' work.

The following rules and tables will at times be found useful to the working plumber; and, in order to make them as simple as possible, I will begin by explaining the law of falling bodies, which, if understood, will enable the workman to calculate the flow of water through pipes by gravitation. I shall also give rules for ascertaining the amount of friction, or loss of head of water, when running through long pipes and bends; the method of calculating the amount of water a pump will throw; power required to work it, and such like. But it should be distinctly understood that simplicity is the great thing aimed at, and therefore in some cases the plain figures will not answer for theoretical work, but in all cases it will answer every purpose for the practical plumber.

Gravitation;

Or the law of falling bodies, which governs the flow of water when falling through pipes (also for suction pipes).—The plumber, in order that he may tell the quantity of water which will flow through a suction pipe, or from a cistern through a given sized pipe into a w.c., &c., in a given time, should make himself thoroughly acquainted with the following rules of gravitation or attraction, or law of falling bodies.

Falling Bodies.

A body falling from a height will, approximately speaking, fall 16ft. in the first second of time; but in reality it falls 16ft. 1in., which latter in practice is not taken into consideration. Say, 16ft. in the first second of time, it will, in the second second, fall three times this distance—viz., 48ft.; five times 16ft. in the third second; seven times that in the fourth second, and so on: its velocity increasing during every successive second as the odd numbers run—viz., 1, 3, 5, 7, 9, 11, 13, 15, &c., the result of which will be found in the following table:—

Laws of Falling Bodies:

Time of falling in seconds.	Space fallen through.	Space fallen through in last second.	Velocity acquired at the end of the time per second.
1 second.	16 feet.	16 feet.	32 feet.
2 seconds.	64 ,,	48 ,,	64 ,,
3 ,,	144 ,,	80 ,,	96 ,,
4 ,,	256 ,,	112 ,,	128 ,,
5 ,,	400 ,,	144 ,,	160 ,,
6 ,,	576 ,,	176 ,,	192 ,,
7 ,,	784 ,,	208 ,,	224 ,,
8 ,,	1,024 ,,	240 ,,	256 ,,
9 ,,	1,296 ,,	272 ,,	288 ,,
10 ,,	1,600 ,,	304 ,,	320 ,,

Explanation for working the above tables.—For our purpose, and for simplicity's sake, suppose we have a perfectly straight line of vertical piping 16ft. high; now drop a bullet through this pipe and without touching its sides. What will be the velocity acquired at the end of the first second? For answer turn to the table, column 4, which indicates 32ft.

Rule for working.—Multiply the square root of the height by 8; this gives the velocity acquired per second

Example.—$\sqrt{16} = 4 \times 8 = 32$ft. per second. See column 4.

Question.—If a body of water takes 2 seconds in falling, what will be the velocity of the water?

Rule.—Multiply the time by 32; this gives the velocity.

Example.—$2 \times 32 = 64$ft. per second. See column 4, second line.

We have seen that a body will fall in the second second of time at the rate of 64ft. Let us reverse this—The velocity to be 64ft. per second, find the time of its falling.

Rule.—Divide the velocity by 32.

Example.—$64 \div 32 = 2$ seconds.

Question.—If a body takes 3 seconds to fall, find the space fallen through in the last second of time.

Rule.—Multiply the seconds by 2, and this product by 16, and from this product deduct 16; this gives the space fallen through in the last second.

Example.—$3 \times 2 = 6 \times 16 = 96 - 16 = 80$ft.

To find the space fallen through during the 3 seconds of time.

Rule.—Square the seconds and multiply by 16; this gives the space fallen through.

Depth of Wells found by Falling Bodies in Time.

Example.—The square of $3 = 9$; this multiplied by 16 gives 144ft.—the space fallen through in the 3 seconds. This is a very handy rule for ascertaining the depth of wells and height of buildings, &c., without actual measurement.

To find the time of falling.

Question.—The height of a falling body being 144ft., how long is it falling?

Rule.—Divide the height by 16, and the square root of this will give the time in seconds.

Example.—$144\text{ft.} \div 16 = 9$, and the square root of $9 = 3$, the number of seconds in falling.

Flow of Water by Gravitation.

To find the quantity of water that will flow by gravitation through a given sized pipe in a given time; class of pipe not to be taken into consideration, but worked by the above rule, which in reality is an approximation. Smooth-bored pipes, of course, will deliver a larger proportion of water than those having rough surfaces.

Glass Pipes and Friction of Water.

A glass pipe having the same bore as an ordinary iron one, will deliver considerably more water in a given time. An ordinary leaden pipe must be the assumed pipe to be taken into consideration.

Question.—Say the height to be 36ft. and the pipe a 2in., time one hour.

Example.—$\sqrt{36} = 6 \times 8 = 48$ft. per second $\times$ 3,600 seconds per hour = 172,800 $\div$ 3 = 57,600yds. of water per hour; having these 57,600yds. of 2in. pipe, what is its content?

Rule.—Square the diameter of the pipe in inches, and multiply by the yards in length; divide this product by 10, which will give the content in gallons.

Example—

$$\frac{2^2 \times 57600}{10} = 23040$$

gallons per hour.

If required per minute, divide by 60, and if per second, divide the last quotient by 60 again. Thus, 23,040 gallons per hour is 384 gallons per minute, and 6·4 gallons per second.

I may here mention that an allowance of 10 per cent. is at times made for loss by friction; but this greatly depends upon the class of pipe, and, if required in minute detail, it may be calculated by the following rules:—

$$G = \left(\frac{(3d)^5 \times H}{L}\right)^{\frac{1}{2}}$$

$$H = \frac{G^2 \times L}{(3d)^5}$$

$$d = \left(\frac{G^2 \times L}{H}\right)^{\frac{1}{5}} \div 3$$

$$L = \frac{(3d)^5 \times H}{G^2}$$

In these rules d = diameter of pipe in inches.
L = length in yards.
H = head of water in feet.
G = gallons per minute.

Then, again, there is the loss of head by bends, junctions, or branches, &c., the latter especially, which cause great eddies, more especially when the junctions are made at right angles.

Capacity of Pipes, Pumps, &c.

Question.—What are the contents of a pipe of given bore and length, say, 2in. bore and 24ft. long?

Rule.—Square the diameter of the pipe in inches, and multiply by the yards in length, and divide the product by 10, which will give the contents in gallons.

Example.—$2 \times 2 = 4 \times 8$ yards (or the 24ft.) $= 32 \div 10 = 3\frac{1}{5}$ gallons.

Having now seen the rules of gravitation and ascertained the quantity of water which will approximately flow by gravity through different sized pipes, I will give a rule for approximately ascertaining the quantity of water which different sizes will deliver per hour.

Pump Table (Computation of).

Question.—What amount of water in gallons will a pump whose barrel is, say, 3in. in diameter, with a 10in. stroke, worked 30 times per minute, give (theoretically) per hour?

Rule.—Square the diameter of the barrel in inches, and multiply this by the length of the stroke in inches, and again multiply by the number of strokes per minute, and also multiply by 60, the minutes per hour; now divide the product by 353, and the quotient will be the gallons delivered per hour.

Example.—Square of $3 = 9 \times 10 = 90$. Now, $90 \times 30 = 2700 \times 60 = \frac{162000}{353} = 458$ gals. per hour.

(*For power to work the above, see Horse Power.*)

Pump Barrel Proportions.

To find the size of barrel required to raise a certain number of gallons per hour with a 10in. stroke, worked 30 times per minute. Suppose 1835·460 gallons are to be raised per hour.

Rule.—Multiply the number of gallons by 353 and divide by 60, then divide this quotient by the number of strokes per minute, say 30, and again by the length of the stroke, which is, say, 10in., and the square root of this last quotient gives the size of barrel.

Example.—1835·460 $\times$ 353 $\div$ 60 $\div$ 30 $\div$ 10 = 35·99541, and $\sqrt{35{\cdot}99541} = 6$, nearly.

Here we get a number, but it is not practically correct for lift or jack pumps as usually fixed, for the simple reason that cup leathers leak, or, in other words, let by a certain portion of the water between the sides of the cup leather and barrel, to say nothing of the water which often passes the bucket clack. The loss of water pumped per minute will be in proportion to the tightness of the bucket with the sides of the barrel, &c. For this it is usual to make an allowance of from 10 to 15 per cent., which reduces the quantity of water which would be delivered accordingly. It should be noted that if the pump bucket fits the barrel so that no water passes, it must of necessity be very tight, and then there would be a considerable loss of power by unnecessary friction.

Horse Power, Pump Power, or the Power required to work a Pump.

It should be first of all known what a horse-power signifies. This is calculated from a powerful full-grown horse; he should, when fresh, be able to raise, by suitable machinery, 33,000lb. to a height of 1ft. in one minute of time when walking in a straight line upon the level ground, but when going up a hill he cannot do the above amount of work by, say, ordinarily speaking, about three-fifths of the quantity; but as horses do not walk in a straight line when turning a pump, it may be asked when does the horse exert its strength to the best advantage when doing circular work. From experience the circle should not be less than 40ft. in diameter, and if the circle be reduced to half, namely, 20ft., the horse's power will be reduced two-fifths of the above 33,000lb.

Question.—Raise 400 gallons per minute to a height of 28ft., what power will be required?

Rule.—Multiply the weight of water, which is 10lb. to the gallon, in lbs. delivered per minute by the height to which it is raised in feet, and divide the product by 33,000, and the quotient is the horse-power.

Example.—$400 \times 10 \times 28 \div 33{,}000 = 3{\cdot}39$ h.p. (For pressure to the square inch on pump bucket and capacity of barrel, see examples.) But although these figures are here as 3·39 h.p., it would be impossible for three horses to do anything like this amount of work in pumping water, even though they may be working in a 40ft. circle, for the simple reason that in all pumps there is a certain amount of friction, and this friction in practice becomes a serious item. Generally speaking, you may take it for granted that it will amount to at least from 20 to 25 per cent.: besides, a horse, like men, does not want to be always exerting its maximum power, nor would a good owner allow such to be done.

Pump Labour.

The following table at sight gives the number of gallons which may be raised by a man, ass, or horse to the height of 1ft. in one minute of time with the ordinary pumps, according to certain durations of work in hours, from four to ten hours a day, and is the result of practical work. For increased heights divide the number of gallons by the additional height in feet.

TABLE (REGISTERED).

No. of hours at work.	Horse.	Ass.	Man with winch.	Man with lever.
	No. of gals.	No. of gals.	No. of gals.	No. of gals.
From 1 to 4	1,653	475	249	205
„ „ 5	1,480	410	222	183
„ „ 6	1,350	374	203	167
„ „ 8	1,169	323	176	145
„ „ 10	1,040	290	157	130

For the necessary sized barrel, see Pump Table (Computation of).

Manual Power Pumps and Gearing.

We have seen what one horse-power signifies, and know the necessary quantity of power required to work a pump of a given size, whose duty it is to lift water to a given height. The average strength of an ordinary labouring man is about one-eighth (though some writers say one-fifth) the strength of a horse—viz., he can raise 4,125lb. 1ft. high per minute. That is to say, eight powerful men pulling at their best advantage can equal the strength of a good horse, and can accomplish the same amount of work; but take notice that the horse worked under the best advantage, so should the man. The horse works best when pulling in a straight level line, and is equal to twenty-seven men when pulling in a line with the horizon.

A man exerts the greatest strength when pulling upwards from the height of his knee, as in pulling from the knees upwards to the level of his hips, as when pulling the winch of an ordinary wheel pump, and he exerts the least power when he is pushing horizontally from about his own height. Suppose a man when turning a winch to be able to exert 25lb. continuously the day through, if he has a mate turning the winch in the opposite side, that is to say, each to pull and push alternately, as with the frame shown at Fig. 881, where from Q to about frame high the man does the best amount of work; and take notice of the difference of the winches 1 and 2 in Fig. 877, where they are there purposely shown wrongly to illustrate this example, but may easily be arranged as those in Fig. 855.

The two men when working the frame Fig. 881, can raise 60lb. instead of 50, or 10lb. more than when the handles are as shown at Fig. 877, because in Fig. 881 at the weakest point of the one man is the strongest point of the other, so much so that an advantage of 10lb. is gained, and the men work more comfortably. Of course, I am speaking here of work appertaining to that done by horse and man when pumping with ordinary every-day pumps, and for the man the work done will be greater if a proportionately balanced flywheel, to counteract the weight of the pump rods, &c., be used. Or where a flywheel is not employed, put this balance at the end of the pump lever, or handle. Or this may be done by a balanced lever and weight fixed on the stage or guide stage, so as to pull up the rods, &c., and assist the working generally. Or a weighted chain and pulley wheel may be used.

Pump Gearing (*also see above*).

The mode of ascertaining the proportions suitable for pump gearing is as follows: see Fig. 838. K is the handle of the lever, J the leverage, which is, say, 16in. long. Now suppose the crank (see A, Fig. 883) to be a 4in. or an 8in. throw, then the leverage will be four to one, and if a man should put, say, 25lb. power upon the handle, you would get 25×4 times=100lbs. on the crank. Now take into consideration the cog wheels. Say that the pinion, or small wheel M, Fig. 879, has 20 cogs working into the large spur wheel N, which has, say, 120 cogs: here is a difference of 100—viz., it has six times as many cogs as the pinion wheel, and therefore you gain in power six times, and this added to the power gained by the crank and lever will be as follows:

Example.—Lever power 25lbs. $\times$ 4=100 $\times$ 6=600lbs.; therefore, when 25lbs. is exerted on the handle K we get a pull on the pump rod of 600lbs., bar, say, 10 per cent. for friction, &c. Of course, the number of cogs in the frame, Fig. 879, are shown in smaller numbers than those quoted in the example, and may be varied to suit circumstances, or an extra two or three wheels may be employed, which, of course, entirely depends upon circumstances, the power of which may be computed by the rule laid down; size of wheels and number of cogs to be of the same proportions.

Question.—To find the proportions of levers and wheels of a frame suitable for lifting, say, 700lbs. weight on a pump-rod.

Rule.—First obtain the work to be done, which is, in this case, say, 700lbs. Next multiply this by the radius of the driver pinion or wheel M, Fig. 879, and the crank in inches, and divide the product by the power in lbs. (this power is that which you apply on the handle). Now divide the quotient by the length of the winch in inches, and the result is the radius of the large spur wheel N in inches.

Example.—700lbs. $\times$ 2in., the radius of pinion wheel = 1,400lbs. $\times$ 5in., the length of crank, = 7,000, and $7{,}000 \div 25$, the power in lbs. on handle, $\div$ 16, the length of winch, = $17\frac{1}{2}$in., the radius for the wheel N.

Overshot Water Wheel Power.

When calculating the power which you can get from a stream, &c., upon a water wheel, measure the depth from the surface of the water to the centre of the orifice of discharge, and extract the square root of the depth, which, multiplied by 5·4, gives the velocity [illegible]d. Now multiply this by the area of the mouth [illegible]nd this gives the amount of water which [illegible]. When this is known the height a[illegible] together with the power to be ga[illegible] calculated.

Example.—Say that 1,000 gallons, or 10,000lbs. of water is flowing or emptying itself into the wheel per hour, and that the fall is 6ft. Here we get 60,000lbs. of power on the wheel per hour, which, theoretically speaking, will raise 60,000lbs. of water 1ft. high, or 10,000lbs. 6ft. high, and so on; but as the wheel never can be expected to give out the same amount of work that it receives, a fair allowance must be made for friction, &c., and in practice you may safely reckon the loss to be at least 25 per cent., though some engineers say one-seventh.

Rule.—1,000 gallons × 10lbs. = 10,000lbs. × 6ft. = 60,000lbs. power received per hour, less 25 per cent. for friction = 45,000lbs. raised 1ft. per hour. If per minute, divide by 60.

Pipe Area in Square Inches of Round Pipes and Pump Barrels (Registered).

(Also see Displacement of Water in Pumps, Pipes, &c.)

Diameter. Inches.	Area. Inches.	Diameter. Inches of the nearest size Pipe made.	Area. Inches.	Diameter. Inches.	Area. Inches.
¼	·049	2	3·141	6	28·274
⅜	·110	2½	4·908	7	38·480
½	·196	3	7·068	8	50·26
¾	·441	3½	9·621	12	113·00
1	·7854	4	12·568	16	201·00
1¼	1·227	5	19·635	24	452·40
1½	1·767	—	—	—	—

This table is useful in finding at a glance the quantity or number of square inches contained in a pipe or pump-barrel from ¼in. to 24in., which, by calculating the height or perpendicular lift of the water in feet, reckoning 1lb. to 2ft., or by the more accurate rule before explained (see Weight of Water, &c.), will give the number of lbs. required to pull up the bucket, or otherwise to lift the vertical column of water, whose base is any of the above areas.

This table will also be found exceedingly useful to plumbers and gasfitters when laying down mains for supplying a given number of branches. For argument, say it is required to fix eighty ⅜in. pipes throughout a building, what will be the size of the main pipe to equal in bore this number of small pipes?

Rule.—80 × ·110, the area of the ⅜in. pipes, = 8·8in. square, then look in the right-hand column for the nearest figure containing these number of square inches, and this will give the size of the main pipe required.

Of course, the same rule applies when supplying a number of cottages with water; but in all cases the diminished head and friction must be taken into consideration, for the first branch would receive the full pressure of the water, and the last one its minimum head, and, of course, the main pipe must be at intervals reduced proportionately to the number of jets taken off.

Pipe Proportional Scale.

This instrument consists of a piece of zinc or cardboard shape of the above, as shown, cut into inches, &c., of course, must be large enough to do the work

the pipe K to be 5in., and L 4½in. in diameter, nto a branch pipe J, and it being required to find the proper diameter for the branch pipe. Proceed with the scale as follows: From 5 on the divisional edge to 4½ on the other, draw a line as shown by the dotted line, and the length of this line, measured with the same scale (viz., 5in.), will be the length for the diameter of the branch pipe, which will be 6¾in.; but suppose the pipe J to be the given size pipe of, say, 6¾in., delivering into a 5in. outlet, as at K, and it is required to know what other size pipe J will supply, as at L. For this, take the divisional point 5 on

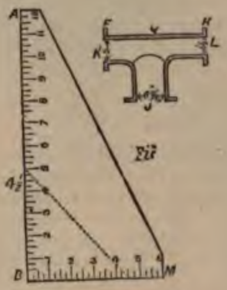


FIG 924

the edge as a centre, with the 6¾in. radius describe an arc, cutting the outer divided edge, and the number which the point of the compasses cuts will show the diameter of the pipe required. This will be on the divisional line 4½in.

The following is a simple table suitable for ordinary plumbing work and gasfitting, which gives the number of branches which may be taken off pipes of various diameters ranging from ⅛in. branch pipe to 3in., and main pipes from ½in. to 5in.

P. J. Davies' Branch Pipe and Main Table (Registered).

Diameter of Branch Pipes.											Diam. of Main Pipes.
⅛ in.	¼ in.	⅜ in.	½ in.	¾ in.	1 in.	1¼ in.	1½ in.	2 in.	2½ in.	3 in.	Inch.
16	4	1									½
36	9	4	2								¾
64	16	7	4	1							1
100	25	11	6	3							1¼
144	36	16	9	4	2						1½
256	64	28	16	7	4	2½					2
400	100	44	25	11	6	4	3	2			2½
576	144	64	35	16	9	6	4	2			3
1024	256	114	64	28	16	10	7	4	2½		4
1600	400	117	100	44	24	16	12	6	4	3	5

Rule for computing the number of branches which one main pipe will supply. Multiply the square of the diameter of the main pipe in eighths, and divide by the diameter of branch pipes in eighths.

Say that it is required to supply a building with 256 ⅛in. gas pipes or fountain jets, what size main pipe will you require? For this look in the left-hand column of table for the number 256, and opposite to this, in the main pipe column, will be found the size of main pipe required.

Now, suppose you have 64 ⅛in. pipes, 16 ¼in. pipes, 7 ⅜in. pipes, 4 ½in. pipes, 1 ¾in. pipe, what size main pipe will you require to supply these branches?

Rule.— 64 ⅛in. pipes = 64 eighths.
16 ¼in. ,, = 64 ,,
7 ⅜in. ,, = 63 ,,
4 ½in. ,, = 64 ,,
1 ¾in. ,, = 36 ,,
Total...291 ,,

Here we have a total of 291 eighths, which, being divided by 64, gives 4·3906 circular inches, which, by referring back to the table of pipe and pump barrel areas, will give you the size of the main pipe required—viz., 2½in.

Displacement of Water in Pump Barrels 12in. long, in gallons.

Also for pipes, but to be multiplied in feet according to their various lengths. (Theoretically, only allow 10 per cent. for escape of water past cup leathers, pistons, and such like.)

Diameter in inches.	Area. Sq. inch.	Displacement. Gallons.	Diameter in inches.	Area. Sq. inch.	Displacement. Gallons.
12	113·0	4·881	3¼	8·295	·3583
11½	103·8	4·484	3	7·068	·3053
11	95·03	4·105	2¾	5·939	·2565
10½	86·59	3·740	2½	4·908	·2120
10	78·54	3·393	2¼	3·976	·1717
9½	70·88	3·062	2	3·141	·1356
9	63·61	2·747	1¾	2·405	·1038
8½	56·74	2·451	1½	1·767	·0763
8	50·26	2·171	1⅜	1·484	·0641
7½	44·17	1·908	1¼	1·227	·0530
7	38·48	1·662	1⅛	·9940	·0429
6½	33·18	1·433	1	·7854	·0339
6	28·27	1·221	⅞	·6013	·0259
5½	23·75	1·026	¾	·4417	·0190
5	19·63	·8480	⅝	·3068	·0132
4½	15·90	·6868	½	·1963	·0084
4	12.56	·5426	⅜	·1104	·0047
3¾	11·04	·4769	¼	·0490	·0021
3½	9·621	·4156	⅛	·0122	·0005

Pulsometers.

These pumps are exceedingly useful for contractors, or for places where large quantities of water are required to be pumped in the least possible time.

2nd.—They are exceedingly useful where exhaust steam would be a nuisance.

3rd.—They have no working parts, excepting just the valves.

4th.—They can be used in out of the way places where it would be difficult to apply any other class of pump or injector.

5th.—They can be made to force water to almost any height, dependent upon the pressure in the boiler.

The pulsometer, Fig. 925, consists of a single casting called the body, which is composed of two chambers (AA) joined side by side, with tapering necks bent towards each other, and surmounted by another casting called the neck (J) accurately fitted and bolted to it, in which the two passages terminate in a common steam chamber, where the ball valve (I) is fitted so as to be capable of oscillation between seats formed in the junction. Downwards, the chambers (AA) are connected with the suction passage (C), wherein the inlet or suction valves (EE) are arranged. A discharge chamber, common to both chambers, and leading to the discharge pipe is also provided, and this also contains one or two valves (FF), according to the purpose to be fulfilled by the pump. The air-chamber (B) communicates with the suction. The suction and discharge chambers are closed by covers (HH) accurately fitted to the outlets by planed joints, and readily removed when access to the valves is required; in the larger sizes hand holes are provided in these covers. (GG) are guards which control the amount of opening of the valves (EE). Small air-cocks are screwed into the cylinders and air-chamber, for use as will be hereafter described. These are the general outlines

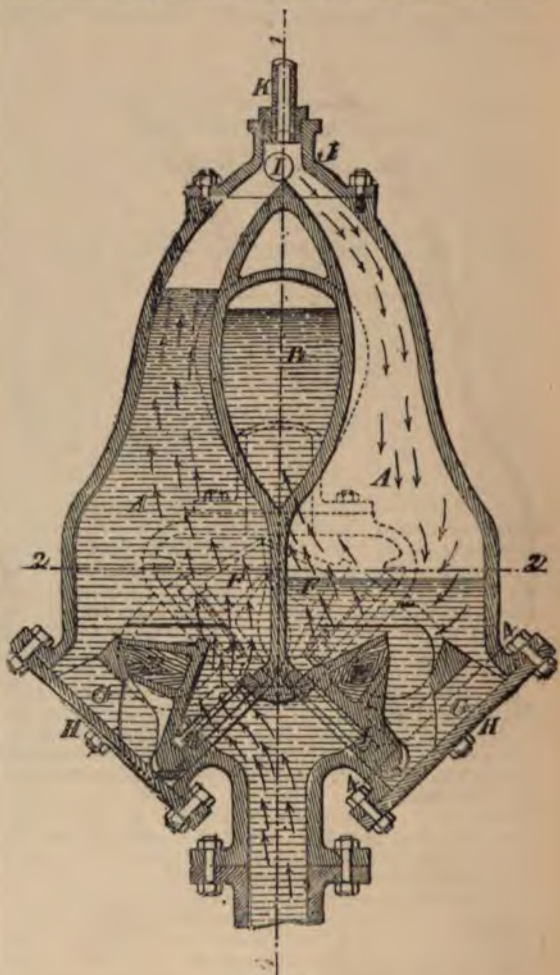


Fig. 925.

of the construction of the apparatus, and they are sufficient for the understanding of the nature of its operations.

The pump being filled with water, either by pouring water through the plug hole in the chamber (see the elevation, Fig. 927), or by drawing the charge, as can readily be done, is ready for work. Steam being admitted through the steam pipe (K) (by opening to a small extent the stop-valve) passes down that side of the steam neck which is left open to it by the position of the steam ball, and presses upon the small surface of water in the chamber which is exposed to it, *depressing it without any*

agitation, and, consequently, with but very slight condensation, and driving it through the discharge opening and valve into the rising-main.

The moment that the level of the water is as low as the horizontal orifice which leads to the discharge, the steam blows through with a certain amount of violence, and being brought into intimate contact with the water in the pipes leading to the discharge chamber, *an instantaneous condensation takes place*, and a vacuum is in consequence so rapidly formed in the just emptied chamber that the steam ball is pulled over into the seat opposite to that which it had occupied during the emptying of the chamber, closing its upper orifice and preventing the further admission of steam, allowing the vacuum to be completed; water rushes in immediately through the suction pipe, lifting the inlet valve (E), and rapidly fills the chamber (A) again. Matters are now in exactly the same state in the second chamber as they were in the first chamber when the description commenced, and the same results ensue. The change is so rapid that, even without an air vessel on the delivery, but little pause is visible in the flow of water, and the stream is, under favourable circumstances, very nearly continuous. Air-cocks are introduced to prevent the too rapid filling of the chambers on low lifts and for other purposes, and a very little practice will enable any unskilled workman or boy so to set them by the small nut that the best effect may be produced. The action of the steam ball is certain, and no matter how long the pump may have been standing, it will start as soon as dry steam is admitted.

The steam ball, if once made true, wears itself and its seats true, as it *turns in its bed* at every stroke, so that no part of its surface falls twice in succession upon the seat.

Fig. 926 shows the pulsometer with flexible valves, and Fig. 927 is an elevation of the pulsometer.

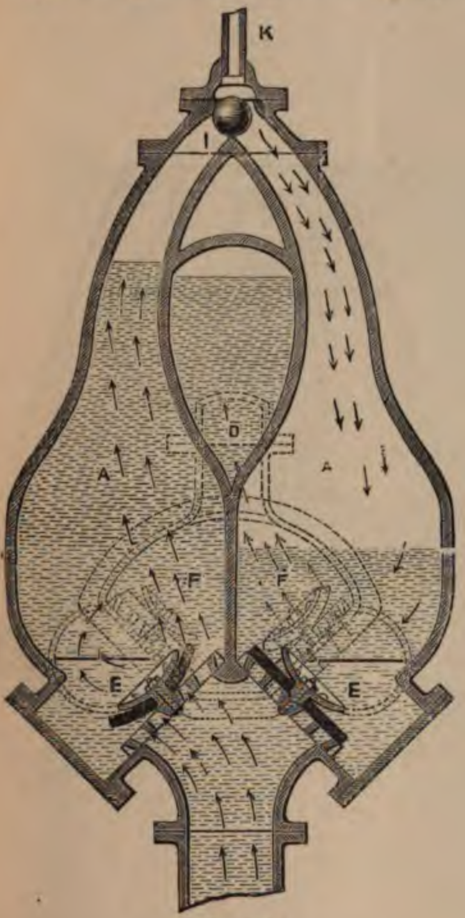


Fig. 926.

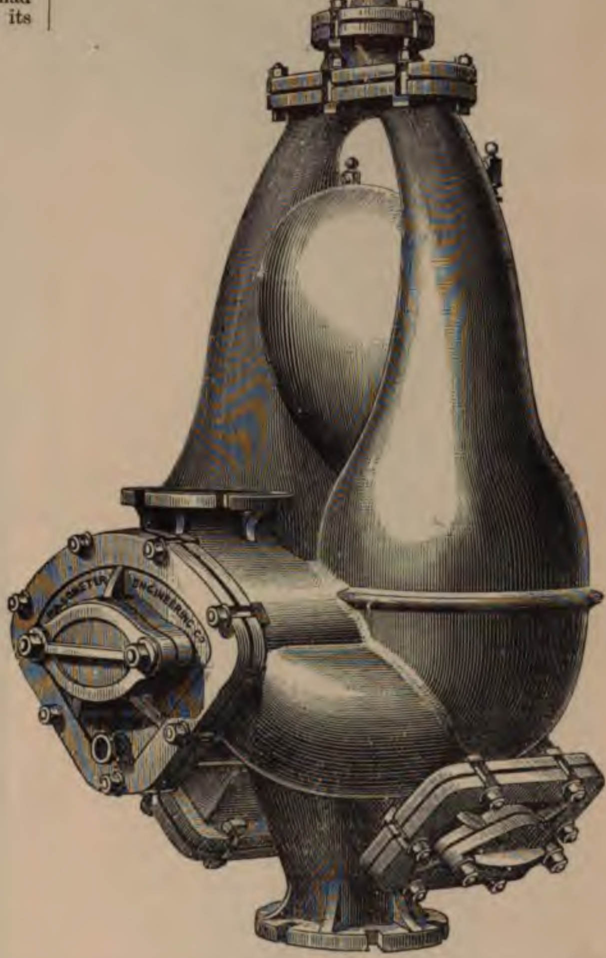


Fig. 927.

The advantages enumerated as belonging specially to the pulsometer in its portability, its ability to raise sand, &c., without injury, its small size and cost and general handiness, will naturally suggest its adoption, and have already established its reputation for the above purpose.

The annexed woodcut, Fig. 928, shows the way in which it can be most easily set to work, and it will be evident that at a very small expense it can be lowered as the water in the excavation, well, or coffer-dam is lowered; additional lengths of rising-main being added from above as required. By its use in this way contractors have in many instances been enabled to overcome difficulties which, with other kinds of pumps, seemed insuperable.

Well-sinking and fixing and recovering Deep-Well Pumps with Pulsometer.

ADDITIONAL ADVANTAGES.

1.—Owing to the small horizontal area occupied by the pulsometer, it can be lowered through small and confined spaces between rods, stages, &c., where it would be impossible to place the ordinary kinds of pumps.

2.—There is no exhaust steam, and therefore the well is not heated up.

FIG. 928.

Pumping Sewage and Sewage Sludge from Settling Tanks, and raising Mud from the bottom of Rivers.

The pulsometer will successfully raise liquids in which there is a very large amount of matter in suspension, and has proved itself very suitable for the purposes above mentioned.

Pulsometers are very good for pumping water into or out of swimming baths, and after what I have written upon this class of pump, Fig. 929 will be readily understood.

Swimming Bath.

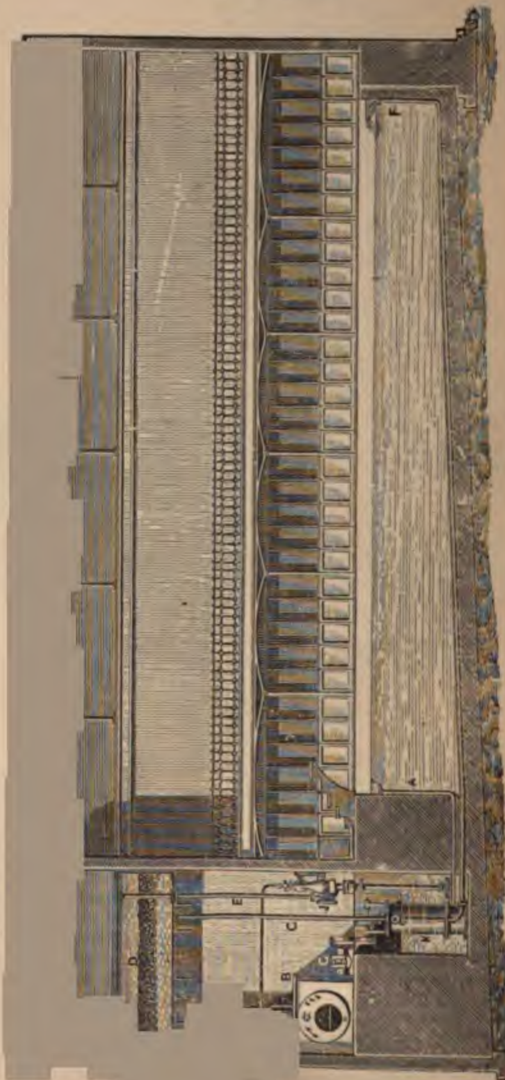


FIG. 929.

Fountains.

Nearly everyone in the trade has at one time or another had a turn at fountain construction ; in fact, nearly every plumber's apprentice boy goes in for such during his apprenticeship. Many ingenious devices have been brought out by such men as Heronis, Hero, and the like, long before the Christian era, and pneumatics, with hydrostatics, largely figure in their works to construct artificial fountains in the shape of an air vessel, see Fig. 943. Assume the fountain dish, Fig. 934, to be placed on the pipe at G, Fig. 943, and a small jet fixed to play into this dish under air pressure, here you can quickly construct a fountain which will play for a time or until the air or water is exhausted. Should it be air, then add an air pump (a simple cup leather nailed on a wood plunger will answer) on at C, and pump more air into the vessel, and the fountain is off again till the water is all out. Then let the water run back, *via* a suitable stopcock and pipe, or by a little simple contrivance the waste water may be arranged to run back into the air chamber as Hero's fountain does; and by this the motion of a column of water is transmitted to another column by the interposition of a body of air between the two. The column of the water compresses the air on the water surface of a lower chamber, and this air is transmitted to the chamber above, and thence upon the surface of the water, which causes the water to run up a suitable pipe to a jet.

FIG. 930.

There is one thing which I wish to guard the young plumber against, and this is, the cherishing of a silly idea about making water run or move of its own accord, viz., to cause a fountain, waterwheel, &c., to work, by using the same water over and over again, or by attempting what is known as perpetual motion. I write this, because nearly all my younger brethren are most likely at one time or another to fall into this mobile, viz., before he is thoroughly master of the principles of mechanics. In a word, it must be borne

FIG. 931A.

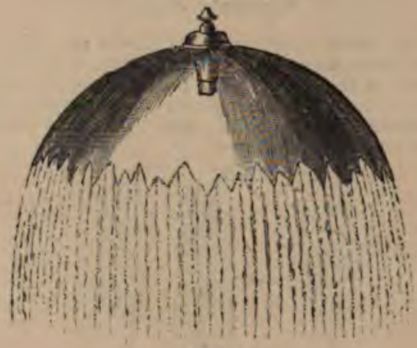


FIG. 931B.

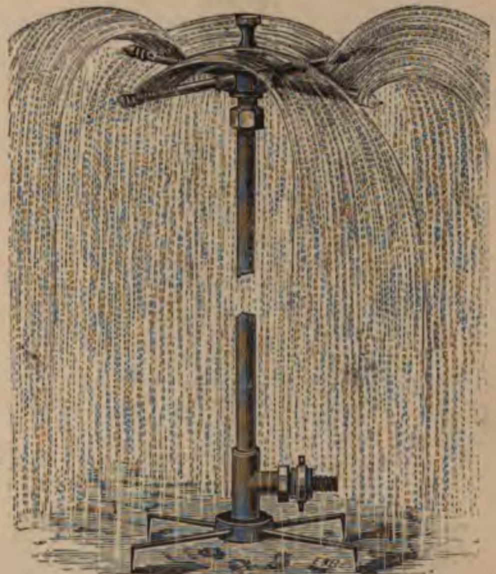


FIG. 932.

in mind, whatever moves as an agent or a motive power, that no matter of itself can possibly be made to shift its position without some cause for applied force.

FIG. 933.

Fountain Jets.

The jets are of importance, and there are only a few that can make these to my satisfaction. Fig. 930 is an illustration of the basket jet and ball, a very pretty arrangement for a window, or other places where people would be likely to stand to look on, for some of the antics which this ball cuts are marvellous.

Fig. 931A is the convolvulus jet, and Fig. 931B is a dome jet: both are very pretty jets.

Fig. 932 is the Barker mill or reaction sprinkler fountain, for lawns, &c., and is a very interesting jet, especially in country places, where I have seen people wondering what makes it revolve.

Fig. 933 is the patent Oriental revolving lawn sprinkler and fountain jet, a compact and cheap sprinkler, which will throw the water over a circular area up to 40ft. in diameter, according to the pressure. It distributes the water very evenly over the ground, and is another of these interesting whirling appliances.

All these jets are obtainable from Messrs. Tylor &

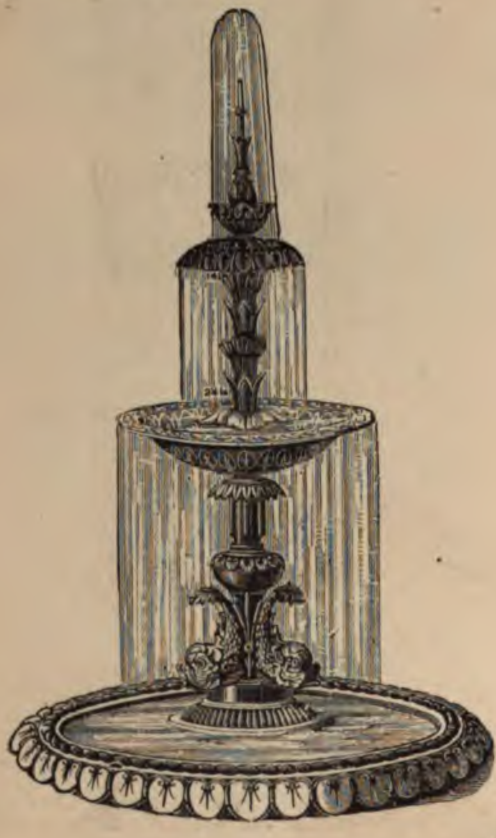


FIG. 934.

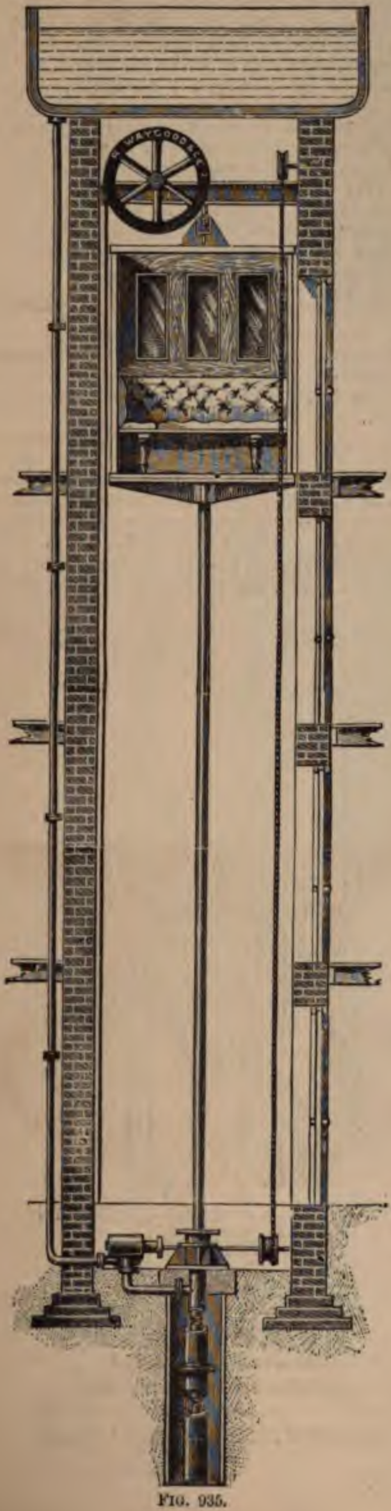
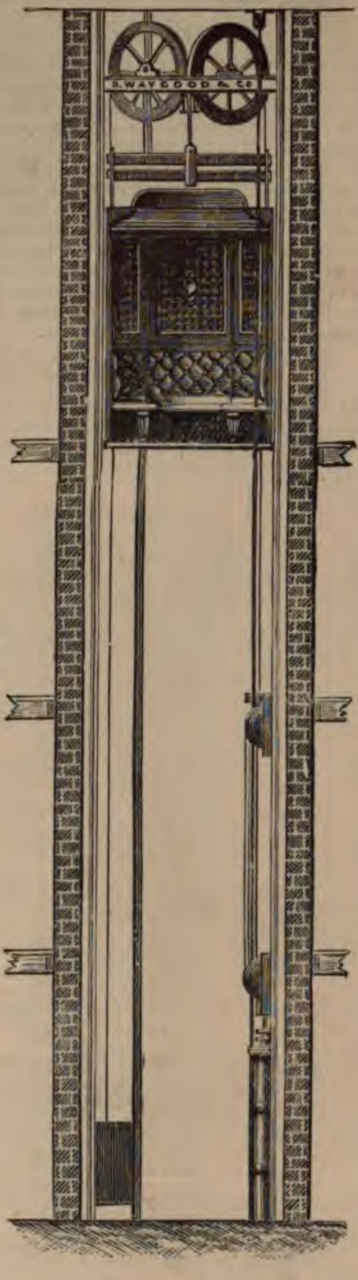
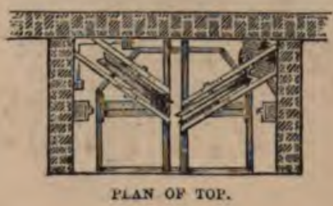


FIG. 935.





PLAN OF TOP.

FIG. 936.

Fountain Vases.

There are thousands of different ways to make a fountain from a simple jet to that shown on the left-hand side of Fig. 934, which is a splendid piece of workmanship by Messrs. Newton, Chambers & Co., and may be had from 52in. bottom basin to any diameter.

This fountain can be fitted with jets to play out of the dolphin mouths, and in a variety of other ways. For the best results of jets for fountains, see Fire Engine Nozzles.

Fig. 934, on the right-hand side, illustrates a very handsome vase, made by Messrs. Newton, Chambers & Co., and may be used for a small window or hall fountain. The pipes can be brought up through the centre of the vase, and the overflow standing waste perforated, so that fish may not pass away through the waste pipe.

Fitting-up Fountains.

In fitting fountains of large or small sizes, there is nothing to equal leaden pipes for all branches, because you can bend them to any angle, which is of great importance in directing the jet, and there are always two main points to keep in view. First, the size of the pipes, which should be large enough to prevent loss of head of the water (see Tables, Gravitation, &c.), but for fountain work allow LARGE margins. Say you have a fountain with basin 20ft. diameter, and you require to put in a quantity of ½in. jets to play towards the centre, here is a practical illustration. There are three dozen jets from a 6in. pipe round the outer part of the basin, with 1in. lead pipes about 12in. to 18in. long, with a properly constructed cone shaped 1in. to ½in. screwed brass jet. This, with 50ft. head of water, answers the purpose, but take particular care to have a full way throughout the length of pipes, and if the main be of a long length, say over one mile, that it should be larger in proportion to the length.

The second point to keep well in your mind is to make all bends to a very easy angle. Avoid all elbows, and, where you can, let the water enter the pipes through a cone shaped mouth or inlet; even the jet pipes will be all the better if the inlet ferrule be of a cone shape, say from 1½in. to 1in.

Hydraulic Lifts.

It will be expected of me to give an insight into the principle of hydraulic lifts, of which there are various kinds, but if my reader has carefully read and studied the description and Fig. 916, he will require no further assistance to understand the principle of the lift, Fig. 935. Here, in this figure, the ram, explained in Fig. 916, is

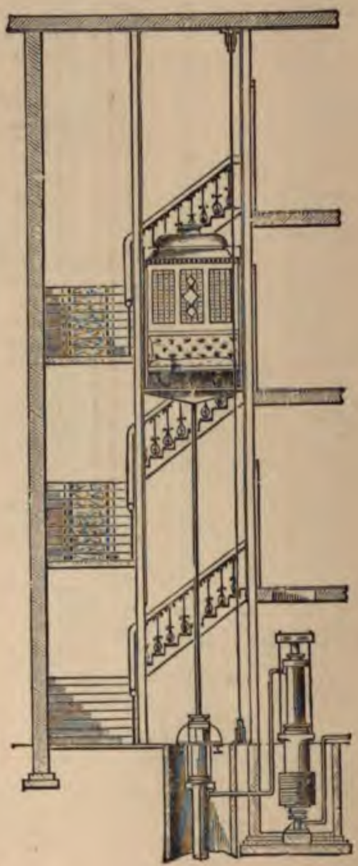


FIG. 937

simply extended in length to suit the height of the lift, Fig. 935. On the right-hand side of the figure can be seen the rope, which actuates the water valve, suitable for turning on or off the water to the hydraulic cylinder. The lift or cage can be balanced by a balance weight with a rope passing over a suitable pulley as shown at the top of the figure.

Fig. 936 is an illustration of a lift working with ropes and pulleys, which are actuated by a short ram or piston in the bottom, and for places where the boring to sink the ram cylinder cannot be allowed.

Dinner Lifts.

Fig. 937 shows a dinner lift; also a small lift suitable for grand staircases.

The Accumulator.

Fig. 938 illustrates an accumulator. I may here remark that what the flywheel is to the engine, so the accumulator is to the press or lift, save and except that the flywheel is capable of exerting a sudden force, whilst the accumulator exerts an equipoised force, generated and accumulated at "slack" times, and returned when busy. In other words, the accumulator is a receiver of power, otherwise often lost when work is not being done, which power can be readily given up at any interval of time. It can be seen that this is simply a cylinder to which a pipe can be attached at the boss near the bottom flange, or at any other point. The rings or weights on the top can be added to suit circumstances. Or, instead of these rings, anything can be made to answer the purpose of the weights, such as old bricks, stone, water, &c.

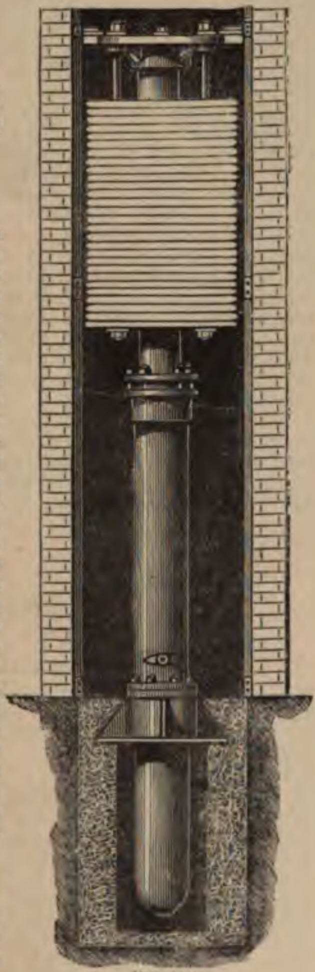


FIG. 938.

Hydraulic Drain Pipe and Joint Tester.

You have seen the machine for testing cocks, Fig. 914. I will now bring before your notice a drain pipe tester, which will be readily understood by the diagram, Fig. 939.

The pipe joint tester is shown at Fig. 940. This is simply two discs or rings of rubber, as shown in the section, and at each end of the joint. These rings are, by means of the screw on top, pressed, which causes them to expand laterally, and against the sides of the pipe; water is then forced from the test pump to any given pressure, and so the joint can be proved without filling the pipes.

Fig. 941 illustrates a water-way plug of solid rubber, G, the latter of which being compressed between the discs E and H by means of a screw actuated by the pipe C, will form a very reliable plug for plugging pipes, whilst through the pipe C water may be forced.

Fig. 939.

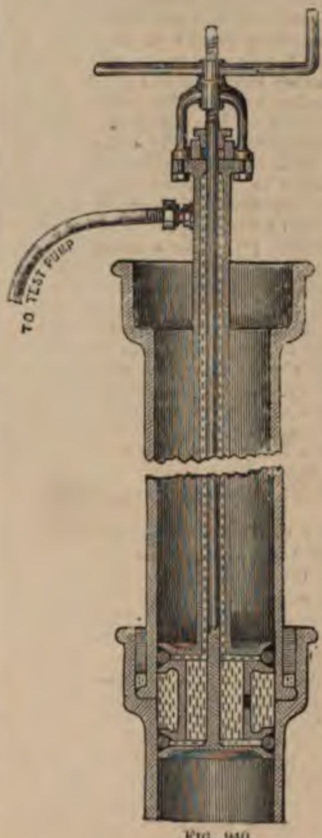


FIG. 940.

FIG. 941.

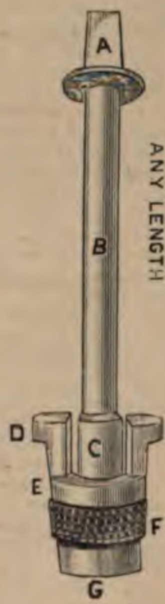


FIG. 942.

Fig. 942 is a patent solid stop plug or fire plug for plugging fire main pipes, and is useful for the above purposes.

HYDRAULIC OR WATER RAMS.

[illegible] self-acting apparatus is the invention (or, [illegible] recorded) of Mr. Whitehurst, of Derby, [illegible] afterwards improved upon by Montgolfier, and [illegible] Montgolfier the younger, Blake, and [illegible] short time after this improvement the [illegible] by a plumber at Bristol, and it [illegible] been many times re-invented by [illegible] many parts of the globe, and has under- [illegible] even until the last year or so. [illegible] upon which this machine works seems, at [illegible] not to be properly understood, or why the [illegible] after it has once closed; but can be now [illegible] attention to the following. The [illegible] simply that of velocity, inertia, [illegible] the latter being caused [illegible] elasticity of the water when [illegible] the valve, which performs a [illegible] machine; and here has been [illegible] found in any proceeding work [illegible]

[illegible] habit of drawing water from [illegible] and especially through [illegible] having *ground in plug cocks*, or [illegible] must have heard a [illegible] in the pipes, which [illegible] crackling noise, like so [illegible] with a hammer. This is [illegible] water upon the end [illegible] the valve, or the key or [illegible] following. Suppose [illegible] pipe, which for this [illegible] one, because when [illegible] little fall, say [illegible] is easier obtained. [illegible] and having a fall [illegible] of water equals, [illegible] acquired a velocity [illegible] the blow struck [illegible] similar to G, [illegible] move with the [illegible] and instantly [illegible] may be computed [illegible] be 5ft. per [illegible] will be 30. [illegible] Water per [illegible] as it ex- [illegible]

sufficient to produce a partial vacuum; then the waste valve in the ram instantly drops in weight equal to 15lbs. to the square inch, plus the weight of the valve. It should also be borne in mind that the water within the trunk of the ram, at the moment when the waste valve closes, is compressed more at the waste valve than in any other part of the trunk, so that the spring or elasticity of the water within the trunk gives its repulse diminishingly, and in ratio according as the molecules are compressed between the inlet and the outlet of the ram.

Before departing from this subject, I should now continue to explain why this noise is heard on long lengths of suction pipes, and more especially in ground-in full-way stopcocks. This requires some further explanation, because you can have an air chamber fixed on the end of the entrance side of the pipe, near the stopcock, yet the chattering sound will be heard. This is due to the fact that there are two ways to produce this, one being due to the before-mentioned cause, and the other to the closing of a valve *behind* a column of water, which does not, like the ram method, instantly cause the column of water to stop in its forward motion, but produces a partial vacuum, in length (and intensity, of course, only to its maximum) according to the weight of the water when in motion, together with the amount of fall.

It is not generally known that even steam, when under pressure, will, when passing through very long lengths of pipe, and when suddenly arrested, make the same chattering noise as the water does when suddenly arrested!!! Also see the account of the Water Hammer.

Split Pipes.

It is a common thing with us plumbers to find pipes split or burst, more especially the rising mains of pumps when worked without air chambers, and it is through such occurrences that we are indebted for the invention of the hydraulic ram.

The plumber before spoken of was engaged at a hospital in Bristol to fix some piping, which was of a long length; the tap was of the ordinary ground-in plug cock pattern, which turned very easily. The act of quickly turning it off arrested the water instantly, and by reason of the momentum produced by the weight of the water, combined with its velocity, caused the pipes to split or burst, and we are told that in this case this phenomenon occurred nearly every time the tap was turned off. (Had a screw-down cock been used this would not have happened, because then the water would have been arrested slowly, owing to the crutch of the key being turned several times before the cock was closed.) However, after several attempts to remedy this evil, but without avail, the plumber soldered a small pipe behind the cock as at B, Fig. 943, and carried the other end back to the top of the cistern, when every time the cock was used the water rushed back with violence. It occurred to the plumber to carry the pipe to a high level, still the water mounted up, and he being determined to investigate the matter, and to find out how high the water would rise, carried the pipe to the top of the buildin[illegible] cistern was provided, and there supplied w[illegible] out trouble or expense, as in the

apparatus seen at Fig. 943. A is the pipe from water supply cistern, C the Y *junction* or branch, I the cock, and B, C, E, F, L, G, the return pipe or rising main.

After what has been explained, it will be evident to all that if the water in A, B is put into motion, and then instantly arrested, it will strike a blow on the key of the cock, and on the standing water in the return pipe C, with a force equal to the weight and momentum generated by the velocity of the running stream. The force of such blow can be determined by reference to the law of momentum in any treatise on mechanics, also in my Pressure Table before referred to, and may be clearly understood from the following. Suppose the height of the column of water to be 60ft., and the area of the pipe to be one square inch: here suppose a foot column of water, whose base is one square inch, to be equal to ½lb. in weight; then we get from the 60ft. column 30lbs. to the square inch at its base, or at B, Fig. 943. These figures are simply put in

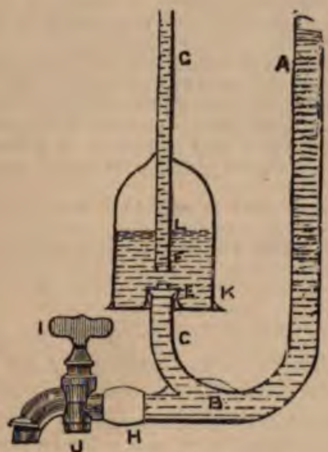


FIG. 943.

round numbers for convenience of calculation, and for those not well up in figures, as is the case with many of my best fellow-workmen. Now, suppose this water to be put in motion, and to have attained a velocity of, say, 20ft. per second. Now let the water be suddenly arrested, and what is the consequence? A blow will be struck on the cock key, and on the stationary water in the bottom of the return pipe C, of a weight not less than 30lbs., multiplied by the velocity, which will equal for so small a machine the enormous weight of 600lbs.; also allow for the length of the pipe or trunk of the ram. The longer this is, the heavier will be the blow, in accordance with the laws of mechanics. This 600lbs. will suddenly put the whole of the water within the pipe C into rapid motion, and strike up the valve E, Fig. 943, when water will be injected from the pipe C into the air chamber L, Fig. 943; and this injection force will in due time compress the air within the air chamber, when the air, as at L, in its turn will softly and regularly press upon the surface of the standing water L, and so cause it to gradually rise in the rising main pipe F G, and to a given height above the source of supply A.

NOTICE.—The pressure of water within the rising main G must never exceed per square inch the *blow* struck per square inch at the waste valve, or, of course, none will enter the air chamber, though the ram may continue to pulsate.

Pulse Valves for Water Rams.

Now, suppose that instead of the tap J being used, we use a self-acting valve C, Fig. 944. (These balls are not the best kind of beat valves.) Here it will be plain that the arrest of the water must be instantaneous, and a better effect can be produced. This is Montgolfier's ram, and an

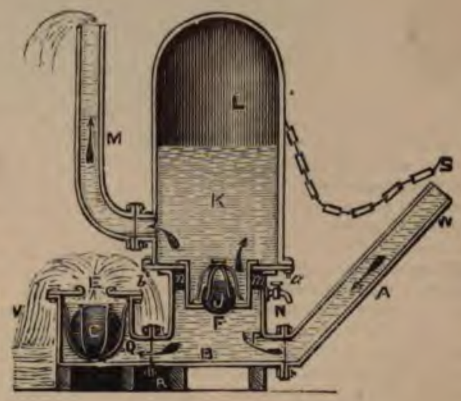


FIG. 944.

improvement upon Whitehurst's, and the ball C is really the very life, so to speak, of the machine, as it causes it to work independently and incessantly without attention. The parts of this machine will be readily understood from the following description:—A, is the trunk of the ram leading from the source of supply; B, the body of the ram; C, the beat, foot, pulse, or waste valve, which will require your particular attention, and will be explained further on, as it is of great importance; J, is the air chamber, retaining or ascension valve, which should be made sufficiently wide, and not to lift too high; L, is the air chamber; and M, the rising main. There should be a head valve S over the mouth of the trunk at W, to stop the ram when not wanted to work. I may be excused for dwelling on this subject so much, but I cannot pass it until I feel that I have exhausted it for the benefit of my younger reader.

The Action of the Ram.

The action is as follows:—Open the head valve S, W, Fig. 944, the water will then, with a velocity due to the height of the fall, run down the trunk as shown by the arrows, when this water will also play round the sides of the ball C and cause it to rise with a jerk and suddenly arrest the water in the body of the ram. Then the water will, by reason of its acquired velocity and very sudden arrest, give a force to all parts of the body of the ram, and consequently the valve J will now move upwards with a momentum equal to the weight and velocity of the water. Now you will notice that at the moment when the waste valve C closes, there is a kind of blow struck, a drive, and a regurgitation, and an immense increase of pressure on the lower internal parts of the ram. This increased pressure lifts the air chamber valve J, and drives a quantity of water through its seating into the air chamber or cushion, and before this valve J is positively closed a *recoil* (at the pulse

valve, and a tendency to produce a vacuum) from the elasticity, or otherwise, of the water in the trunk taking place, which may be assisted by the fall of the valve J, and take particular notice that when this recoil is in action (which is momentary) it tends to create a partial vacuum (for proof, see Snifting Valve account) at the foot of the waste valve C, which, of course, momentarily relieves the lower part of the ram of the internal pressure, and the valve C, when it falls, and allows the water to again run to waste, when the valve C acts as before, incessantly. I have described this in as simple a fashion as possible, and should advise my practical readers who wish to become versed in the groundwork of these machines to make a model ram for themselves as follows:—Let A B, Fig. 943, be a piece of 1in. or 1¼in. lead pipe, or a piece of iron barrel. Take an ordinary 1½in. flat-faced spindle valve and solder it in *upside down* to a piece of, say, 2½in. or 3in. pipe about 4in. long, and wipe the trunk A B into the bottom of the 2½in. or 3in. pipe, and the other end into a cistern; let the spindle of the valve point upward. This 1¼in. pipe will be all the better if laid obliquely, say at an easy angle, because you want a certain length of pipe in all ram work. Now fill the pipe quite full, next knock the valve down so as to open it, and you will find that you will have a hydraulic ram, which will continue in action, but, of course, doing no work. Now branch a ½in. pipe as at B, Fig. 943, and an air chamber with valve as at E, with pipe as at G, and then fill with water as before, and if the pipe G be of only a short length, say as shown in diagram, you will find that the waste valve will not pulsate, simply because the water will urge itself too readily into the air chamber, and the elasticity of the air therein prevents the pulse valve striking with sufficient force to cause a recoil (see account of Snifting Valve), but fix a stopcock on the pipe at G and close it, then fill up as before, and work the outlet valve for a little time until the air in the air chamber becomes compressed, then you will find your model ram once more continue working. Now open your stopcock just a little, and you will find the ram to squirt water. Now continue opening it, and you will find, at a certain point, the ram to cease working, which will at once prove that you, in order to make the machine work, must have a certain amount of weight or pressure in the air chamber to ... assistance to the fall of water from ... working source, so as to get, ... called your attention to, a partial ... waste valve to open.

... we cannot do without having the ... on reflection, this question will ... to the fact that the water in ... pipe is of greater weight ... height for height being taken ... rapid motion and sudden ... and, being so, it is, ... rod of iron in motion, ... prove this, disconnect the ... at R into the side of a ... head of water A, B. ... have the head of water, ... You may also try it with ... to get longer ... vertical head

... supporting the ... important ...

Brief Description of the Action of the Ram.

Refer to Fig. 944. Suppose a stroke has just taken place and the ball C closed, J is open, but only for an instant, for the striking power of the water at F is soon spent, and then the pressure above in the air chamber quickly presses on this valve, which gives the former a backward motion, assisting to press the water back up A, which oscillation partially assists and causes a partial vacuum to take place at C, so that by the atmospheric pressure and the weight of the valve it quickly falls and is instantly ready for another stroke, which quickly takes place; again the water is flung back, the valve J opens at the same time the regurgitation takes place, still assisted by little backwater from the air chamber, the partial vacuum again formed, and so a rocking or oscillating movement is kept up between the water in the trunk A and the water between F and that in the air vessel, the water in the trunk taking short strokes, whilst that at F, J, takes long strokes. There is no question now in my mind but that the closing and opening of the waste valve is due to the above explanation.

You will notice further on that I speak of a secondary air chamber as at N, M, or as at F, Fig. 944, also shown in Montgolfier's Improved at F, Fig. 945. This second air chamber tends to lessen the violence of impact, because then the water has a kind of cushion to partially strike against, instead of its striking its whole force against rigid metal.

I shall now proceed to explain the snifting valve, by using a very old drawing from the hands of Montgolfier, to illustrate the same, but such a ram would not be made to-day.

The Snifting Valve and Secondary Air Vessels.

This snifting valve is for the purpose of supplying fresh air into the air chamber at each pulse or stroke of the ram. The snifting valve is simply a small hole or aperture, as at P, Fig. 945, of capillary bore. In some rams this is left entirely open. It will also be noticed that in this ram there is a second air chamber F within the large one G, and that the beat or foot valve C is of the spindle kind. The use of the snifting valve and the second air chamber will be readily understood from the following description.

Suppose the water to be running down the trunk A, and the beat valve C to give one pulse against the seating Q: the water will then urge itself forward through the body D and strike against E (which is badly arranged—it should be of an easy bend: but such was Montgolfier's ram) and up into the air chamber F; at the same instant the momentum of the water causes a partial vacuum to take place at R (this proves that there is a partial vacuum formed by the regurgitation, and establishes my theory of its action), and to draw in air at the passage or capillary tube P. The air in the smaller air chamber F is not in abundance, or in other words, this air chamber is not too large, therefore the valves J J are not jerked open with so much violence as was the valve J in Fig. 944. You have seen that a small quantity of air can be snifted through the aperture P and into the water. This air, it might be supposed, would return, but it cannot, and for this reason: that part of the water falls back, and instantly fills up the small bore or tube, and the air being lighter than the water, it ascends to the top, and at each pulse this small portion of fresh air enters through the valves J J and finds its way into the larger air chamber H, when it ... floats upon the ... is very necessary, because ...

air chamber, when it is full of air, is of much more value than when only half full, or as shown at Fig. 944. There is also another reason why some makers use the second air chamber: the force of the thumps upon the faces of the valve is greatly diminished, thereby rendering them more lasting.

Now that I have explained the real action of the ram, let us examine the best forms that it should be made to.

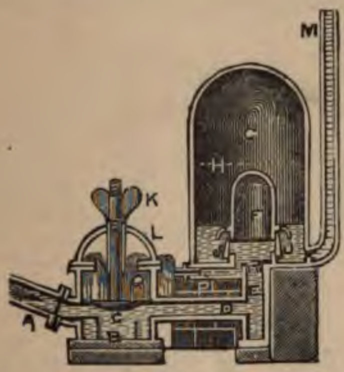


FIG. 945.

That shown at Fig. 945 is unquestionably bad, inasmuch as the water is by the numerous sharp angles much checked before it can strike or lift open the air chamber or the ascending valve. Fig. 944 is better, but the round ball for a foot valve renders it less perfect than it otherwise would be. Now turn to Fig. 946. This ram has a spindle beat valve C, and two air chambers with *spring snifting valve*, which is formed with a kind of bent spring just

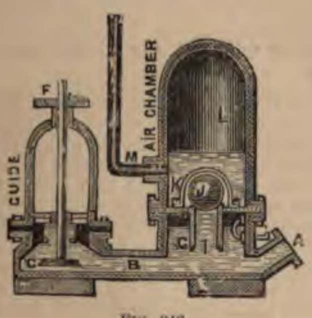


FIG. 946.

above the trunk pipe inlet and near A. This ram is a very good one, though since the date of its manufacture rams have been much improved. I will, however, speak of this one, as I fixed it some thirty years ago near Bromyard, in Herefordshire, and wrote of it about the year 1868 in the *English Mechanic*.

On my last visit to Bromyard, which was twenty-five years after, I was curious to see this ram, and found it working exactly as I left it, save and except a few new foot and chamber valves. This ram is now making thirty-five strokes per minute, and in the same time expends about 22ft. of water in lifting about 1$\frac{1}{2}$ cubic ft. to 38ft. in height.

Fig. 947 is an elevation of a ram having the secondary air chamber and snift hole at E, also a door D for examining the air chamber valve; it also shows the rising main pipe taken off the top of air chamber.

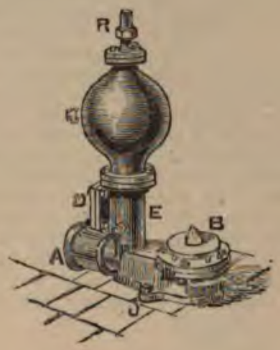


FIG. 947.

Next let us examine Hanson's ram, Fig. 948. This is a sectional elevation of a ram made by an American firm, and although a patent has been taken out for the cup leather air chamber valve, G, the ordinary clack valve is being used. But there is another claim, which is for an additional head valve, D, L, which is supposed to prevent the recoil of water in the trunk, and facilitate

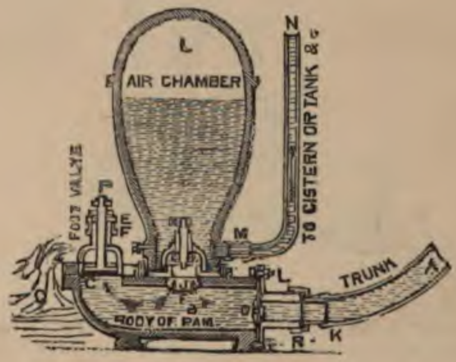


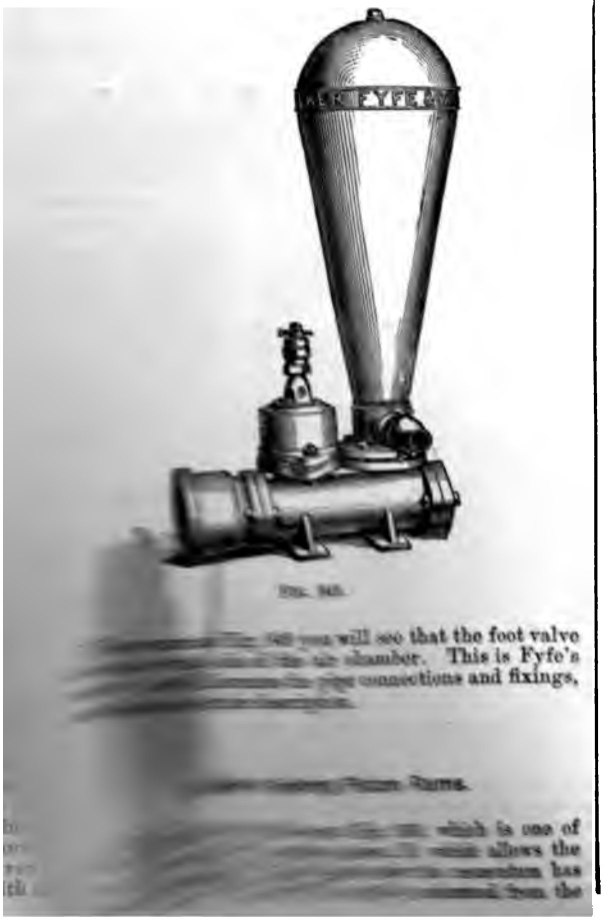
FIG. 948.

the working of the ram. For my part, I fail to see any advantage gained by the use of this valve, but, on the contrary, it is a hindrance to the free flowing of the water into the body of the ram. There is one good feature in this ram: the under side of the foot is roughed, whereby the water seems to take a better hold of the

valve than in Figs. 945 and 946. This diagram also illustrates the method of fixing lead pipes with unions, as at R and M; not to be recommended on the trunk, as it works loose.

For the moment, one would think that the back check valve, D, Fig. 948, would prevent the recoil giving the required vacuum to the waste valve; but this is not so, as the valve D cannot fall quick enough to prevent it.

Take notice that the air chamber, L, Fig. 948, is nearly full of water, and it should be here remarked that by reason of so much water being there the ram is not doing its duty, because the injection water given at each stroke of the ram receives a dead resistance in the shape of a mass of dead or standing water, whereas the air chamber in Fig. 945 is nearly empty of water, and the injected water is received into this air chamber with, comparatively speaking, nothing to impede its progress. Say that the water is injected with a force of 600lbs. to the square inch, and that it is received from the injection pipe into an empty air chamber only having compressed air, to, say, about 200ft. column of water, then, according to our former favourite calculations of 1ft. column to equal ½lb. to the square inch, it only meets with an elastic resistance of 100lbs. to the square inch, leaving a margin of 500lbs. to the square inch, save and except the fractional part required for opening the air chamber valve.



following explanation. When the water flows into the body of the ram, and through the beat valve F, and having acquired sufficient velocity, it closes the foot valve. Its momentum forces up the air chamber valve G, at the same time the water forces the piston D up into the cylinder C; when the recoil, caused by the sudden closing of the foot valve, takes place, the spring at the top of the piston D forces back the piston, thus assisting the recoil in producing the partial vacuum, and making the waste valve more certain in action, and the ram less liable to stop.

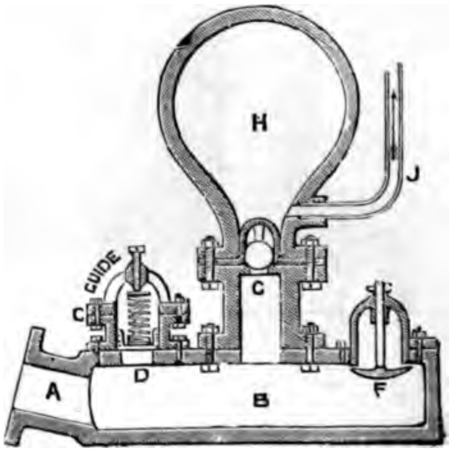


FIG. 950.

I may here mention that I have fixed many of Blake's rams in different parts of the country, and have never had better workers; they do their duty, are strong and not clumsy, and are not liable to stop by inattention, which is one bad fault with most other makers' rams.

Rams without Air Chambers.

Next examine Fig. 951. This, another of Blake's rams, is made to work without the use of the air chamber, a plunger, E, being substituted in its stead, which is held down by the springs H, H, and the cross lever J. It will be plain that when the ram is put into action, that as the water rises from the body of the ram into the pipe D and R, that at every pulse which the foot valve C makes, the momentum of the water will be felt upon the bottom of the piston E, which will cause the piston to jig or rise with a spring at each stroke of the ram. It also follows that the piston E must rise in its cylinder according to the pressure upon its lower face, and will rise in the same proportion as it does in the ordinary accumulator—in fact, this is nothing more than the accumulator, the principle of which I applied to the ram in the year 1870; and in the year 1871, in one of my patents shown, the piston worked from off the rising main, to make the ram self-acting. I also found it, when no air chamber was employed, to work noisily, and I discarded it for my lever arrangement. If you further examine this diagram, Fig. 951, you will there find that the piston E acts as an air chamber; but the sides of this large piston are not very easily kept watertight, and therefore in practice will not act satisfactorily. By referring to [illegible] I may be seen my air chamber and self-

loading accumulator, which I designed, and with my speed indicator pump I placed before a committee at the Society of Art's rooms in the years 1872 and 1873. It will readily be seen that with this air chamber and self-loading accumulator the useful effect of an air vessel is retained, as is also the spring of the piston maintained, and the piston will be loaded with water in exact proportion to the pressure of the water within the rising main. For an example, place the flange W, Fig. 956, over the flange G, Fig. 951, and put the ram into action. The water will

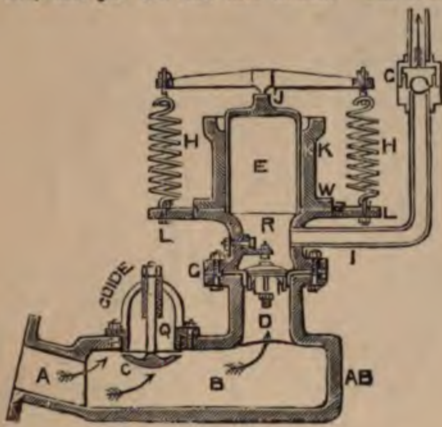


FIG. 951.

then run up the pipe V, and into the air chamber accumulator, when, as it rises in the rising main, so it will also into the accumulator, and so will the weight of the water tend to load the accumulator down. Here, in this diagram, the water cannot escape between the piston and cylinder by reason of the cup leather Q being, by the pressure of the water, forced against the sides of the hollow piston V. Having seen the action of this air chamber and self-loading accumulator in conjunction with water rams, next turn to Fig. 952.

Davies's Self-Starting and Stopping Rams.

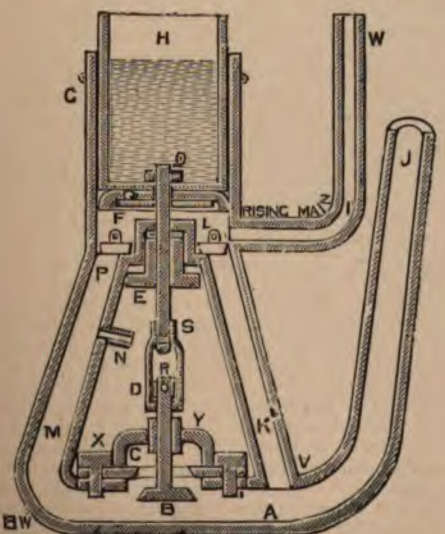


FIG. 952.

Before I explain further, I may be allowed to state that I am totally disinterested in the manufacture of any particular rams, having retired from the manufacturing department of water rams in the year 1876.

In this diagram will be seen a ram worked by my accumulator arrangement, and with two injection pipes K, M, and valves P, L. F is the accumulator, answering the purpose of an air chamber, &c.; J the trunk, and A the body of the ram; W, the rising main; B, the beat valve, which cannot work when the accumulator is under an extra pressure, caused by the closing of the ball and other cocks or valves on the rising main.

Rams with Double-Foot Valves.

This kind of ram is illustrated at Fig. 953. The parts are as follows:—A is the socket for receiving the spigot end of the trunk; C, the flange for fixing the valve plate

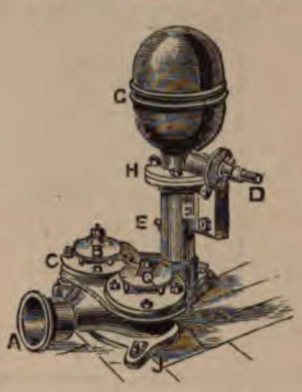


FIG. 953.

over the body; B, O, are the beat valves; D, the outlet or rising main, and G the air chamber.

I fail to see any advantage by the use of two waste valves, but, on the contrary, think that the effect is not so good as with the single valve.

Injection Rams.

It is a common occurrence to make a ram to raise water from a well deeper or from a lower level than the source and outlet of the supply which is required to work the ram. Such rams are sometimes used in quarries, cellars, &c., and are illustrated at Fig. 954. A is the inlet trunk or supply pipe from the head or source of supply. The water runs through this pipe, and gathers round the back of the waste valve D, which causes the valve to close, as in the rams, Figs. 944 and 945, but with this difference: that instead of the body of water being in front of the beat valve D, it is in this case behind it, and, consequently, instead of giving a thrust upon the longer part of the trunk, it tends to suck, or, more properly speaking, to create a partial vacuum. For example: suppose the weight of the column of water from M to the horizontal pipe R to be 5lb. to the square inch, and the water to gain a velocity of 20ft., here we get the 5lb. multiplied by 20, which equals 100lbs., and the momentum will be 100lbs. to the square inch. Now, suppose, for the sake of an illus- tion, the well to be 30ft. deep, and that water is be sucked up, the vacuum pressure required

to the square inch. Here 15lbs. from the 100lbs. leaves 85lbs. as a surplus, which will very well make up for any defect, &c., in the arrangements. I said 30ft. deep,

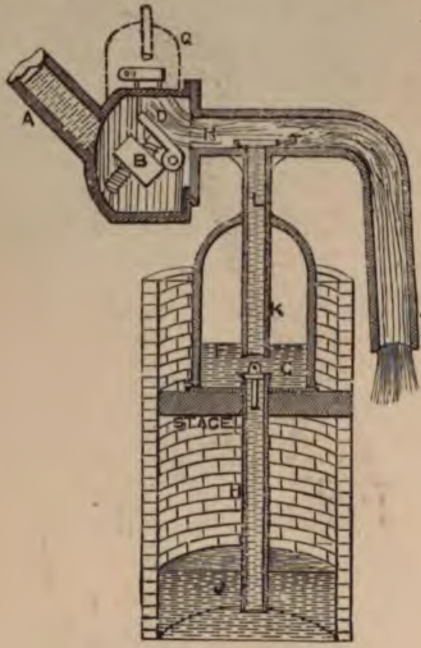


FIG. 954.

but it must be remembered that you cannot work water by vacuum satisfactorily at this distance, more especially if you have valves also to lift, as at C. About 15ft. should be the limit to lift water as above.

Such rams may also be made to throw water as well as to draw it, by lengthening the trunk A, and by placing an air chamber with valve, as shown by the dotted lines at Q. In fact, the various alterations and methods of working the ram are legion, and can only be worked out according to the kind of work required to be done, and by the workman himself

N.B.—Make sure that you put the water and air in the machine exact, as shown, or it will not start work.

FIG. 954A.

Clean and Dirty Water Rams.

Fig. 954A illustrates Fyfe's double action ram, working much about the same as Fig. 954, but with a spring in lieu of the weighted diaphragm.

The rising main is connected on the top union on the right of the ram, as in Fig. 954A, or to a separate air chamber.

The lower union is for the suction pipe, or it may happen that the pure water may be had from a higher level than this union, which, in such case, will be none the worse for being so; in fact, it will enable you to dispense with the diaphragm weight or spring.

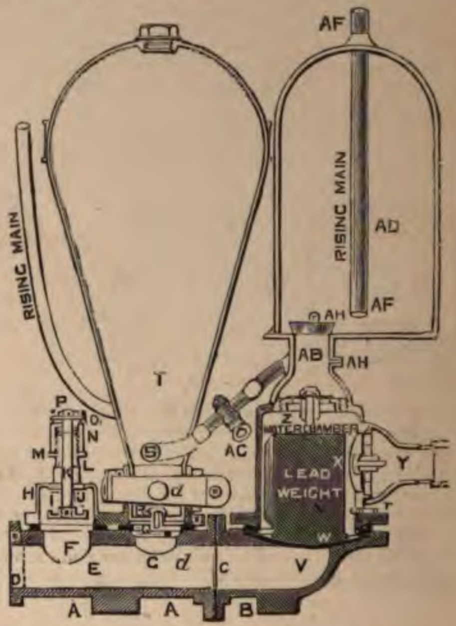


FIG. 955.

This kind of ram is used for the purpose of raising a clean water by means of a dirty water, for an illustration of which see Fig. 955. D is the flange for connecting the trunk, E the body of the ram, I the beat valve, Q the air chamber valve, S the ordinary rising main outlet leading from the air chamber T. Suppose a disc of metal be placed between the flanges as at C, then this machine will do the work of an ordinary ram. But let this pipe be open, and the valve way G Q closed as shown, with the stop-cock *a*, or otherwise, and let W in the water chamber be a thick and weighted indiarubber diaphragm to cover over the waterway in the body, bent downwards, as shown at V. Now, let this chamber Z be full of water, as also the pipes Y and AB, and let the pipe Y have a valve opening into the chamber Z, and on the top of the opening Z let an outlet valve be fixed as shown, to open upwards and into the rising main AB; *d* and AH are the snifting holes, as spoken of in Fig. 944, &c. Suppose all to be as described, and the ram charged with water; let the rising main pipe S be provided with a stopcock AG, to connect the rising main AB, to the air chamber T, or otherwise. This will necessitate only one rising main and one air chamber; but another rising main and air vessel, AD, may be employed. Let the ram be put to work; the pulse valve rises against the seating, and the velocity of the water swings onward, and would cause it to rise through the waterway G, but it

cannot by reason of the stopcock *a*. It swings onward to the underside of the diaphragm V and W, which is thereby beat upwards, and by reason of this upward movement, it forces out the water from the water chamber, through the valve Z, through the pipe AB and valve AH into the air chamber AD, and into the rising main; then the valve Z closes, and the water in the body of the ram being released from pressure by reason of the beat valve opening, the weighted diaphragm falls back, the inlet valve Y opens, and more water is drawn into or enters the water chamber. When this is done the water in the trunk D again starts into motion, and soon, by its accelerated motion, gains a certain inertia, and the beat valve I is again carried forward, which, being suddenly stopped, causes the water in the body to again urge forward, when its momentum again causes the rubber diaphragm V and W to rise, and so on alternately.

Here you may see that the diaphragm valve W really acts as the plunger D in Fig. 950, and yet does double work.

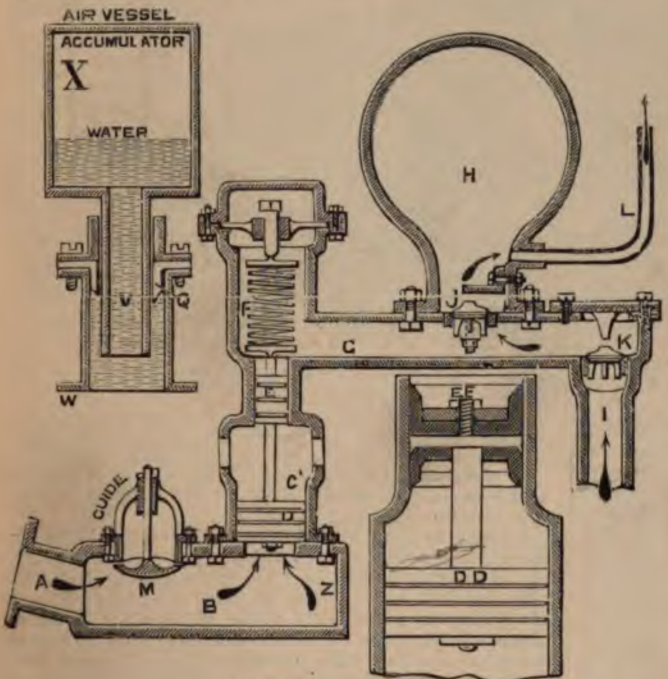


FIG. 956.

Now you have seen that by means of a diaphragm the ram can be made to pump up a different fluid to that by which it is worked. Instead of using a diaphragm a bucket or plunger may be employed—for this refer to Blake's ram, Fig. 956. In this ram may be seen at D a large piston working within the cylinder C, which is branched on the top of the body of the ram. At the other end of the piston rod, and at E, is a piston or cup bucket working upwards. An enlarged view of this piston and cup leather is shown at EE and DD. On the top of the piston is fixed a spring F, to give the downward motion to this cup leather or piston. This draws the water up the suction pipe I, and opens the valve K as in the ordinary plunger pump. Now let the foot valve M close, as in the ordinary manner; the inertia of the water being onward, the water strikes the head of the piston D with a momentum equal to the velocity and weight of the water within the body of the ram. The piston D having received an upward blow or thrust, it is at once communicated to the piston or bucket leather E, which in its turn forces the water onward through the air chamber valve G, and so on into the air chamber H, and up the pipe L. (Notice.—The proper place for this piston D is at the end of the body Z, where it will give the best effect.)

Siphon Rams.

The siphon ram, Fig. 957, is very rarely made, and, in fact, there is not one plumber in a thousand who has seen one; but after the knowledge you have now obtained by working on the foregoing rams, you will be easily

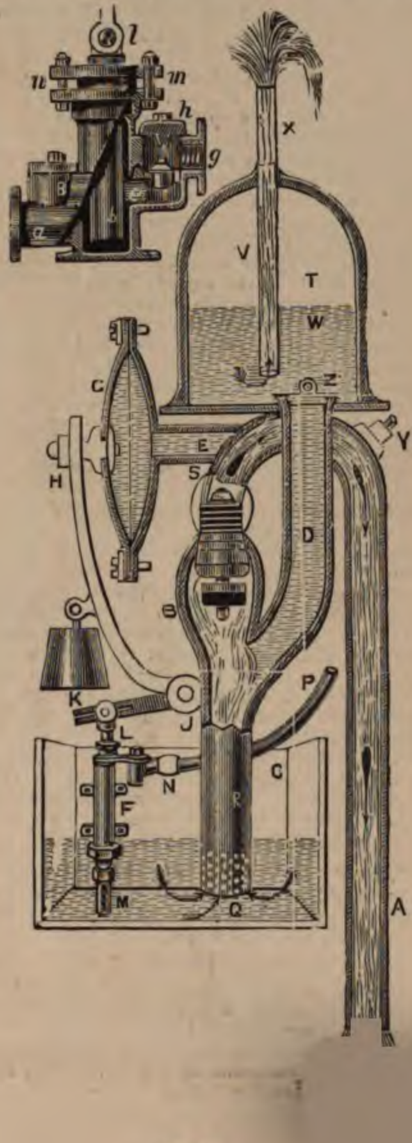


FIG. 957.

enabled to understand this one. This ram is only used in places where the ordinary ram cannot be fixed; for instance, in places where the long leg A may be let down into a deep cavity too awkward to fix the ordinary ram, or in brooks which are likely to be flooded, &c., and where the ram foot valve would be stopped by the weight of water above it, &c. Sometimes a considerable saving in piping may be effected by its use as follows. Suppose the head or spring of water to be on the side of a hill, and a house close to the spring, and that the water is required to be elevated to the top of the house. Now suppose the fall to be 6ft., but in order to get this 6ft. you will have to go a distance of 500 yards, here you can take the trunk A, Fig. 957, 500 yards away, and fix the body B and the short leg C at the spring or well, and so save the 500 yards of rising main.

The action is as follows: Having filled up the trunk and body, as also the pipe R and D (which may be done by opening the screw cap Y), let the ram be put into action. The beat valve closes, and water is injected up the chamber pipe D, and through the valve Z; it then rises up the rising main X, as in the ordinary ram. But by this method of working there is a great loss of the useful effect of the water, because the momentum of the water in the trunk A, by reason of the shut off valve B intervening, has no effect upon the injection pipe D, but is worked simply by the weight of water within the short leg C of the siphon. Now, to get over this difficulty, and to take advantage of the weight of water in the long leg of the siphon, I have invented a suction and force pump ram, which is illustrated at F, and which will be readily understood from the following description. Suppose the water in the trunk A to be put into rapid motion, and the beat valve B to suddenly close as in the ordinary ram. Now suppose the pipe E to be branched on to the trunk as at S, and that G is an elastic diaphragm, piston, or cup leather, which is, or may be, attached to the lever H, or otherwise to the handle of a pump as before said. Suppose the pulse valve B to suddenly arrest the column of water, the weight of the water in the trunk A will tend to create a partial vacuum; and in proportion to the velocity and weight of the water, so will the diaphragm G move inwards, and so work the lever H, which, being jointed at J with the short slotted lever K, will raise the pump piston L, when the effect of the momentum of the water within the trunk is past, so will the weight K bring back the lever H, and with it the diaphragm, and so on alternately. It will be plain that by this method water may be raised to any height required. This diaphragm arrangement may be made to give an outward thrust instead of an inward action, and may be fixed at BW, Fig. 952.

There should be a cock on the outlet trunk at about A, and this outlet dip or trap itself to prevent the trunk too readily emptying itself when not in use. Y is the plug to fill trunk A, &c., with water.

Having described and explained the different rams and their action, I will proceed to show one or two fixed, and describe the modes of fixing, &c. I may first mention that water rams, like all other engines, cannot do work of their own accord, but will be dependent upon some of the prime moving elements, let the power come from where it may. Therefore, the useful effect of this apparatus will be governed by a certain force, generated in this case by a running stream or head of water, and determinable by the *well-known* laws of mechanics. The simplicity of the operation of this machine has been the means of its ranking as one of the most beautiful philosophic instruments which has hitherto figured in the pages of any writer on natural philosophy and hydraulics; and its durability and simplicity renders it decidedly one of the most important and valuable self-acting machines yet developed for raising water. This hydraulic machine is especially useful for forcing water where large quantities can be allowed to run to waste.

Directions for Ordering Rams.

First, state the amount of the fall of water in feet and inches, which you can obtain by damming up or otherwise; second, the amount of water you have running to waste per minute; third, the height to which you require the water lifted in the rising main; fourth, the amount of water you may require raised in the 24 hours; fifth, the horizontal distance of piping required.

FIG. 958.

Of course, as in all cases where long lengths of pipe are used (especially when of small bore), friction must be taken into consideration.

I generally allow for rising main pipes from ½in. to 1in. bore, 1ft. pressure for every 100 yards of piping, that is to say, if the rising main be 1,000 yards long I allow 10ft. extra pressure, *or 5lbs., being ½lb. per foot, as before stated, to the square inch extra on the surface of the water in the air chamber*, to overcome the friction in such pipes. Of course, there are always certain circumstances which must be at times taken into consideration. If the pipes be 1¼in. to 2in., I only allow half this amount, simply because there is not the same amount of friction proportionally (per quantity of water passed) in large pipes as in the smaller ones, the friction being in exact proportion to the size of bore. My advice is, always use pipes large enough for the work.

Let us go back to the fall, and examine what is actually necessary to get a certain required amount of work. Some will say that if they had a head of, say, 10ft., they would make use of the whole, not having to lift the water more than 30ft. I may say that a fall of 10ft. is ample to throw one-fourteenth of the water expended to a height of 140ft., and I may add that it is quite possible to fix a ram under a head of 10ft. and yet get no more work than from under a 5ft. or 6ft. head.

If this be the case, there must of necessity be a lot of useless wear and tear on an ill-proportioned ram. This being so, it [illegible] judgment of the plumber to select a ram whi[illegible] his fall, so that the wear and

tear of the machine may be in strict proportion to the amount of work done, and the economy in keeping the ram in repair will be in accordance.

In order that my readers may calculate what fall is required to safely work a ram to drive water to a given height, I append the following :—About one-seventh part of the water expended can be safely raised to a height of at least five times that of the fall (and when the ram works well as much as eight times), that is to say, suppose the fall to be 5ft., then one-seventh part of the water expended may be raised, which will equal one-seventh part to a height of 25ft., as before said. You can get more, but this is safe reckoning. And, further, I may add that one-fourteenth part of the water expended may be raised to a height of ten times that of the fall, and so on in proportion. To make this quite clear, so that no misunderstanding may arise, I will give another illustration as follows :—If the ram be placed under a head, say, of 5ft. of water upon the trunk, then for every seven gallons drawn from the head one gallon may, and should be sent through the rising main to a height of 25ft., or half a gallon to the height of 50ft.; or, with a 10ft. fall, for every fourteen gallons expended

FIG. 959.

one gallon may be raised 100ft. high, and so on in proportion. So that it will be plain that the higher the water has to be lifted, the more water will be expended at the beat valve.

Hydraulic Ram Table.

Size of Ram.	Quantity of running water which may be obtained per minute from source of supply.	Length of Trunk.	Size of Trunk.	Weight of lead pipe, the fall not to exceed 10ft. If of greater fall, use a stouter pipe.	Size of rising main, for substance of table, size of pipe (see Lead Pipe Rising Main).
No.	Gals.		Inches.		Inches.
2	½ to 2	From	¾	32lb. to 15ft.	½
3	2 to 4	10ft.	1	56	½
4	3 to 7	to	1¼ to 1½	56 and 72,10ft.	¾
5	7 to 14	60ft.	1½ to 2	72 and 96	1
6	10 to 25		2½	112	1¼
7	20 to 50		3	130	1½
8	30 to 80		4	200	2

The above is a table of the size of pipes used in connection with different makers' rams, according to the quantity of water obtainable.

Of course, the quantity raised will be, as before stated, in strict accordance with the quantity consumed, and the height of the fall; and I may add that if the fall be not very great, and the water supply weak, then a much larger trunk may be used with advantage. Also, I may add, that where a great fall can be obtained, the ram may be of a smaller size than those fixed under low heads of water, that is to say, suppose a brook to be furnishing 9 gallons per minute, with a fall of, say, 10ft., and you use a No. 5 ram to raise a given quantity; then, should your fall be only, say, 3ft. or 4ft., use a No. 6 or 7 ram for obtaining the same quantity, and bank, weir, or dam up accordingly. If the supply of water is abundant, and a large supply is required, then in many instances it will be best to fix two rams, so that whilst the one is stopped for repairs, &c., the other may be kept at work, or both may be worked together. One rising main will answer, especially if a pair of check valves, as shown at B, Fig. 794, are used to prevent the water backing on each other's air chamber.

Hydraulic Ram at Work.

The hydraulic ram, as illustrated, set up, and in action at Fig. 958, is shown for our purpose exposed, but should be well protected from the frost. It is an excellent ram, and will work in strict accordance with what I have written on single-action rams.

The diagram, Fig. 959, is Blake's celebrated double-action ram, as fixed for throwing water to great heights, and one which will answer to what I have written, and illustrated at Figs. 950 and 956, which needs no further description, excepting that these rams are made to throw water 450ft., and the others to force water to the enormous height of 1,500ft. Figs. 947 and 953 may be had from Messrs. Hayward Tyler & Co.

Their No. 1 ram, with 1½in. trunk and ¾in. rising main, will, when the fall is not less than one in ten, deliver from 300 gallons to 500 gallons in 24 hours. (This expression, one in ten, simply means that for a rising main whose height is, say, 50ft., a fall for the trunk should be obtained of 5ft., and so on in proportion.)

Their No. 2 ram, with 2in. trunk and 1in. rising main, will deliver 800 to 1,200 gallons in 24 hours. Their No. 3, with 2½in. trunk and 1½in. rising main, will deliver 1,500 to 2,500 gallons; and their No. 4, with 3in. trunk and 2in. rising main, will deliver 3,000 to 4,000 gallons in the 24 hours, and at the expenditure of water from 8 to 12 gallons to one raised, which, of course, will be according to the height of delivery pipe, &c.

Although I have written so much in favour of this machine, of course I do not mean to imply that we have no better, or, as far as water is concerned, no more economical machines for raising it, that is to say, *where only a limited quantity can be obtained*, or is necessary for the working of the machine itself, because if we come to that point, there is no machine equal to the overshot water wheel, shown at Fig. 899, but what I wish to imply is this: that the ram is, of all water machines, the most simple, and will answer every purpose in places where large quantities of water may be had to run to waste.

The ram will work pretty well under an 18in. head of water; yet, like the water wheel, the greater the fall, and the better the supply of water applied, the more water can be thrown, and, of course, the more powerful will be the machine, though, be it understood, that it is quite possible to have too *great a fall*, and therefore the fall should be only in due proportion to the requirements of the machine, or that the right sized ram should be selected for the particular fall of water.

The relative proportion between the water raised and that wasted, is entirely dependent upon the f

supply, that is to say, from the top of the trunk as at S to the foot valve C, Fig. 944, and the height to which the water is required to be raised.

A fair idea of the amount of work to be done by these machines may be gathered from the following series of tests on some of Messrs. W. W. Fyfe's rams, Figs. 949 and 954A, the correctness of which is attested by Mr. Baldwin Latham, C.E., F.G.S., &c.

TEST 1.

Size of drive pipe, 3in.; size of valve, 3in.; length of drive pipe, 53ft. Fall = **5·83ft.** (5ft. 10in.) Lift = **427·8ft.**—indicated by pressure gauge = **73·4 times the fall.**

TEST 2.

Size of drive pipe, 3in.; size of valve, 3in.; length of drive pipe, 53ft. Fall = **6·04ft.** (6ft. ½in.) Lift = **42ft.** Quantity used in driving = 3 galls. in 15 seconds = 12 galls per min. Quantity raised = 3 galls. in 110 seconds = 1·636 galls. per min.

$$\therefore \frac{\text{Work} = 1{\cdot}636 \times 42 = 68{\cdot}712}{\text{Power} = 13{\cdot}636 \times 6{\cdot}04 = 82{\cdot}36144} = \mathbf{{\cdot}834\ effective\ duty.}$$

TEST 3.

Size of drive pipe, 3in.; size of valve, 3in.; length of drive pipe, 53ft. Fall = **1·23ft.** (14¾in.) Lift = **161ft.** —indicated by pressure gauge = **130·9 times the fall.**

TEST 4.

Size of drive pipe, 3in; size of valve, 3in.; length of drive pipe, 53ft. Fall = **1·19ft.** (14¼in.) Lift = **42ft.** Quantity used for driving = 3 galls. in 17 seconds = 10·59 per min. Quantity raised = 3 galls. in 933 seconds = ·193 per min.

$$\therefore \frac{\text{Work} = {\cdot}193 \times 42 = 8{\cdot}106}{\text{Power} = 10{\cdot}783 \times 1{\cdot}19 = 12{\cdot}831} = \mathbf{{\cdot}631\ effective\ duty.}$$

TEST 5

Size of drive pipe, 3in.; size of valve, 3in.; length of drive pipe, 53ft. B. Pattern.—Pumping Ram. Fall = **5·07ft.** (5ft. ⅞in.) Lift = **349·8ft.**—indicated by pressure gauge = **68·9 times the fall.**

TEST 6.

Size of drive pipe, 3in.; size of valve, 3in.; length of drive pipe, 53ft. Fall = 6·04ft. Lift = 42ft. Quantity used in driving = 3 galls. in 13 seconds = 13·84 per min. Quantity raised (separate spring water) 3 galls. in 131 seconds = 1·37 per min.

$$\therefore \frac{\text{Work} = 1{\cdot}37 \times 42 = 57{\cdot}54}{\text{Power} = 13{\cdot}84 \times 6{\cdot}04 = 83{\cdot}59} = \mathbf{{\cdot}688\ effective\ duty.}$$

Double Acting Ram, Fig. 954A.

TEST 7.

Size of drive pipe, 3in.; size of valve, 3in.; length of drive pipe, 53ft. C Pattern.—Double Acting Ram. (Driving and Spring Water delivered in equal portions.) Fall = 6·04ft. Lift = 42ft. Quantity used in driving 3 galls. in 13 seconds = 13·84 per min. Quantity raised 3 galls. in 105 seconds = 1·714 per min.

$$\therefore \frac{\text{Work} = 1{\cdot}714 \times 42 = 71{\cdot}988}{\text{Power} = 14{\cdot}697 \times 6{\cdot}04 = 88{\cdot}769} = \mathbf{{\cdot}811\ effective\ duty.}$$

NOTE.—In Tests 2 and 4 the water raised is added to that used as having been expended. In Test 6 there is no loss whatever of the spring water raised; whilst in Test 7 half the quantity is added to power.

You will observe that all these drives or trunks were 53ft. long and 3in. diameter. The valves were 3in. diameter entire, only the strokes altered.

No rules can EXACTLY apply to this matter; but the quantities given in the table are based on the height being eight times the fall. If the height is greater, the machine must be larger; if less, a smaller ram will do. The drive pipe is, of course, the trunk pipe.

Directions for Fixing a Ram.

First the length of the trunk should be at least 16 times as long as the fall of the water supply. Say you have 2ft. fall, then the trunk should be 32ft., though some makers, under certain circumstances, fix their rams to work with trunks not more than half this length, but for getting the full power out of a ram then the 16ft. trunk to 2ft. fall works very well.

The ram must be fixed as shown at Fig. 958, upon a good solid foundation of concrete having a good oak frame, or better, a good thick stone, say 6in. to 12in. thick, dependent upon the size of the ram, and to stand out 12in. beyond the face or bed of the ram. The stone should have holes drilled through for strong bolts, so that the lot can be firmly screwed together. It is quite as well if the bed stone be fixed before the concrete is properly set, and in such a manner that the stone shall bed itself well into the concrete with a layer of 12in. all round the sides of the stone, and let the stone bed three parts of its thickness into the concrete.

The bed stone must be fixed at a level so that the waste water shall have the full benefit of the fall, but it must be also fixed at such a level that the waste valve will always work out of the tail water. Take particular care that the bed stone is fixed perfectly level, and take care when building the house for the ram, as at Fig. 959, that it is large enough; leave 2ft. 6in. to 3ft. space all round the ram, and build it frost-proof.

The strainer, if one be used on the inlet of the trunk, should be fixed so that it can be got at for cleaning, and out of the way of frost.

Fix the trunk valve in a manner easy to get at. It is as well to fix an air cock in the middle or thereabouts of the trunk to let out the air should the reservoir become empty, and the trunk fixed in such a position that the confined air can escape. Be sure and make the trunk sound to the ram; this is very important, or the same may soon become leaky, and the ram will stop or become refractory, requiring a lot of attention. Some people fix a stopcock or a check valve near the air chamber on the rising main, as at G, H, Fig. 951, to keep the water up when the air chamber valve is being renewed, &c. It is also a good plan to fix an emptying cock on the rising main for draining it when repairs, &c., are required; it also enables you to empty the pipes during frost, &c. Gauge cocks fixed here and there on the main will always be useful to ascertain whether the ram is at work or not.

A draw-off cock fixed at the bottom of the air chamber is useful to empty the same, and is advisable, and also another at a higher level to let in air is at times useful.

General Management.

Sometimes when your ram is first started it will not make another stroke; in this case keep working the pulse or waste valve up and down with the hand, foot, or as best you can, and you may have to do this until you have got sufficient water into the air chamber and pipes to give a certain pressure.

A stopcock on the main, at about J, Fig. 950, will greatly assist in generating pressure quickly, which may be opened gradually as the pressure increases. At other times the air chamber may be full of water; in this case the ram makes more noise, and will beat quicker. Here the water must be removed, then work th[illegible] before explained, and it should work p[illegible] not work satisfactorily if the [illegible], but the quantity of w[illegible] If the waste v[illegible]

the last-mentioned defect will show itself. If possible, never let the supply water get below the mouth of the trunk, or air will be drawn and stop the ram. When stopping the ram, it is quite as well to stop it at the waste valve, unless it be for repairs. If air be within the trunk, the ram will go upon fits and starts, beating quickly and then slowly, and, anyhow, this is a sure sign of air. If you have no air cock, then hold down the waste valve for a few minutes; this may get the water into a sufficient rush to blow the air out. If this will not do it, shut the trunk valve and take off the waste valve: then let water run through, and refix valve. It should then be right.

Be sure that the snift hole (if any be used) is always clear of the tail water, or it will be useless.

If the water from the rising main be delivered in a spurt or irregular jet, the air chamber is not large enough, or it has too much water in it. A rattling in the rising main is caused by the above faults.

The number of beats per minute can be regulated by the amount of lift you give the waste valve. The greater the lift the slower the working, but the stronger the jet of water sent into the air chamber. (See my experiments with the beat valve.)

Hydraulic Ram Beat Valve Experiments and Cheaply made Ram.

I have experimentalised upon the beat valve in all manner of ways, both large and small, and find great variations therefrom, according to certain conditions.

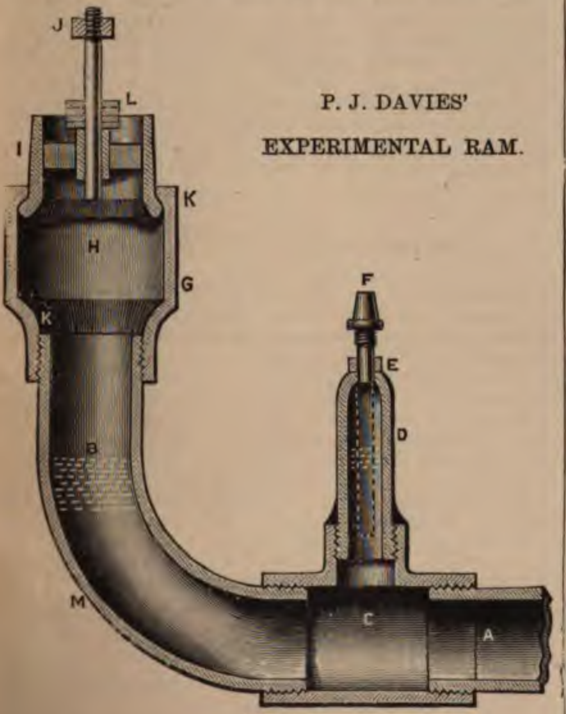


FIG. 959*.

A beat valve should be free to act tolerably sound on its seating, and the weight and lift judiciously arranged, according to the length of the drive pipe, and head of water. I will not trouble you to read the batch of experiments which I have been on for this last twenty years, and from which little or nothing may be gained, more than I have here delineated, but will show you my simple experimental ram, which is such that every apprentice plumber can experimentalise with for himself.

First of all get a 1¼in. to 1in. reducing socket, as shown at G, Fig. 959*, and tin the larger end. Then get a 1¼in. or 1⅛in. spindle valve, shown at I, ground in with not too much taper: let the spindle be made in such a manner that the valve will work, at least, 1in. strokes. Now solder this spindle valve with its head downwards into the large end of the reducing socket, as at K, and in such a way that the valve will have freedom to work, and the centre of the valve to be as near the centre of the socket as possible, so as to come in the water way. Next screw the socket on to a short easy bend B, and the bend on to a tee, as at C, and fix a short piece of iron pipe, as at D, or D may be a bit of lead knocked round, or a bit of lead soldered on to a piece of iron pipe, and screw a 1in. union, Fig. 973, thereto, or a piece of 1in. iron pipe into the tee, as at A, when for your experiments you may run this to any length, or you can make your length up with a coil of 1in. pipe, soldered on to the union or A. E is the end of a lead-burner's finger pipe, soldered on to D and F, the lead-burner's jet. Here is the whole thing complete.

Let the other end of the pipe A go into a tub of water, whose height is, say, 5ft., and which may be kept nearly constant by a ball tap or otherwise, and you have an experimental ram, which can be converted into a very useful and philosophical machine, especially if you put a valve into the pipe D, to answer as a retaining valve, and carry your pipe to any desired place; in such a case make D a 2in. pipe, to a fairish length, and bring down the pipe E, as shown by the dotted lines, which will answer as an air vessel, but this is not required for simple experimental purposes. Assuming now all to be made as shown; fill up the pipes as best you can, and push down the beat valve H for a time or two, when the water will begin to flow, and the beat valve in a second or so will close, and if there is *no air in the pipes*, and F very small, or better for a start, nearly closed, you will find if the valve H is all right, will fall back, and water will run when it will again close, and so on in time, proportionally, with a length of trunk, or drive pipe A, and height of water, and the length of the stroke of the beat valve, viz., from J to L.

It is not absolutely necessary that the drive pipe should have a regular slanting fall, as it may be made to run along the ground, or even a little uphill, providing you get the fall, nor is it absolutely necessary to fix the beat valve exactly face upwards, as it will work in almost any position to nearly the horizontal line, but is preferably fixed upright by most firms.

Now assume everything to be made as suggested, and which will cost but very little, especially if a coil of, say, No. 45lbs. lead 1in. pipe be used, as it can be used for other purposes. The height of the valve is regulated by the washers L, and the following should be the results, but which will vary with the least difference in size of valve, length of stroke, height of fall, length of pipe, smoothness of pipe, and even barometrical pressure; in fact, the erratic movement of the beat valve, under certain conditions, is past all conception. The following are some of its antics.

Assuming you to have a 60ft. length of drive pipe, and just starting it. The valve, under certain conditions, may be made to beat very slowly, then it will increase in speed, and go at a rare pace, when all at once it will assume a much slower pace, and you think it stopped, when off it starts again, very likely to settle down to one regular rate for a time; then alters its rate, just as though th water parted in the middle of the pipes, and vacuum at this point, which I believe it do

This also happens in drive pipes varying from three to four hundred feet long, when the blow in such pipes at times is enormous, and sometimes enough to blow off the soldered-on valve from the socket.

I may here remark that of all the experiments, including the bacterioscopic examination, that I have met with for this work, there is none to equal the funny and intricate movements of this valve, which, by examination of the table, and which is exactly what has taken place, an intelligent reader should readily discover. I don't wonder that no other record of this extraordinary philosophical instrument, the beat valve, and the hydraulic ram, has never been before worked out or published. It is astonishing the amount of ignorance shown by assumingly good engineers on this question. Everyone, without exception, laid it down either that the valve dropped of its own weight, or by some unknown cause, until some years ago I experimentalised and discovered its true action, viz., the elasticity and regurgitation of the water itself, forming a partial vacuum below the valve, and thus causing its fall, which idea was severely ridiculed by many know-alls in trade journals, but which subject now is a settled point, even by those who thought fit to sneer when I first expressed my views upon the subject.

Water-hammer in Steam Pipes.—Boiler Explosions.

Before we leave the subject of the hydraulic rams let us examine the curious phenomenon of the water-hammer, which will instruct the ingenious.

The action familiarly known as "water-hammer" had been long known to the plumber, hot-water and steam fitter, and especially to the engineer who has had much to do with steam power (such as laundry and brew-house), and its singular effects had been often observed and commented upon.

When a pipe is filled with steam, and then has introduced into it a quantity of cold water, or when a pipe, itself cold, and containing cold water, even in small quantities, and without pressure, has steam from a plain open pipe turned into it, the first contact of the two fluids is accompanied by a sudden condensation, which causes a sharp snapping series of quick blows to be struck, usually at the point of entrance; and sometimes a succession of such blows occur, which are the heavier as the pipe is larger, and may be startling, and, under certain conditions, dangerous.

It is not quite a settled point as to what action takes place in all cases, or what conditions are most favourable to the development of the tremendous pressures which are often produced. Perhaps the action is as follows:—

The steam, at entrance, passes over, or comes in contact with the surface of the cold water standing in the pipe. Condensation occurs, at first very slowly, but presently more quickly, and then so rapidly that the surface of contact between the two fluids is broken, and condensation is completed with a suddenness that produces a vacuum. The water surrounding this vacuum is next projected violently from all sides into this vacuous space, and crossing it, strikes upon the surface surrounding it. As water is very elastic and nearly incompressible, the blow thus struck is like that of a solid body, and the intensity of the resulting pressure is the greater as the distance through which the portion of surface attacked can yield is less. In this manner enormous pressures are sometimes produced. (This is the cause of many of our terrible and unexplained boiler explosions which happen during the time when no work is being done, and when the *fire is out.*)

In some cases it seems certain that such pressures may be caused at points in the pipe far from either end, and from the point of entrance of the steam. For example, a pipe may lie in a nearly or quite horizontal line, and if not fully drained, may contain a considerable quantity of water lying in the lower portion, while the steam may flow in above it. The passage of this steam along the surface of the water may cause a disturbance of this water, and being gradually increased as the flow of steam becomes more rapid, may finally cause a break in the surface of the water, which disturbance may produce more rapid condensation and still further agitate the mass, until condensation occurs with such rapidity that a vacuum is formed at the point of greatest action. The next result is the rushing of steam from both directions towards this point, carrying with it, as it goes, masses of water which, coming from opposite directions with enormous velocity, meet at the intermediate spot at which the condensation has been most rapid, and being stopped by instant collision, produces a pressure which may only have as its limit the strength of the pipe.

Where pipes are not burst by this action, it is common to see them sprung and twisted out of line, torn from their connections, and, when a succession of shocks occur, as is often the case, the whole line writhes and jumps lengthwise to an extent that is sufficiently serious to cause well-grounded alarm.

Four lengths of 8in. pipe had been split by this action, and it was desired to ascertain whether they remained, in their injured condition, strong enough to bear the ordinary steam pressure of the line from which they were taken. This never rose to above fifty or sixty pounds per square inch. They were therefore subjected, in a proving-machine, to gradually increasing pressures until the already fractured parts were still further injured, the repairs, or rather the patching having been carefully done in such a way that they were not strengthened by it. This was done by putting on soft patches along the line of the split, and securing them by bolts which were set in the line of the split. The patches thus served as simple stop-valves, preventing the exit of the water through the break.

Injectors produced from the Water-hammer.

We have seen the effect of water and steam coming in contact with each other. This was what originally opened up a great industry in the manufacturing of injectors.

I am not here going to give an account of the working of these articles, but only just draw your attention thereto, and to point out to you that the water ram is not the only philosophical instrument which the plumber has to do with, but the above instruments will require to be studied before he can claim to be perfect in his trade. These the plumber will be called upon to fix in the chemical works, on board ship, and other places, such as gasworks, sulphate of ammonia plants, &c., and you will be expected to know the class of tools best suited to your job, and the best way and position to fix them.

In your selection the following rules should be observed:—

(1.) Cost and reliability.

(2.) Nominal cost of fixing.

(3.) The steam pipe should be as short and straight as possible, and the steam valve fixed near.

(4.) Blow steam through the apparatus before putting on the suction, and keep the suction as short as convenient.

The [illegible] you to think about before you come di[illegible]h will be gone into in due time.

[illegible] results of the tests:—

HYDRAULIC RAM BEAT VALVE TABLE.

P. J. Davies's Practical Experiments, for showing the alteration in number of beats under different circumstances.

EXPERIMENT No. 1. 1in. Lead Pipe.

Length of Trunk.	Fall.	Length of Stroke of Beat Valve.	Valve Beats per 30 Seconds.	Height of Jet thrown.	Size of Jet.	REMARKS.
ft. in.	ft. in.	Inch.		Feet.	Inch.	
60 0	5 6	1	16	35	$\frac{1}{12}$	
60 0	5 6	1	15	—	—	Blank pipe.
60 0	5 6	$\frac{1}{2}$	19	30	$\frac{1}{12}$	
60 0	5 6	$\frac{1}{4}$	27	26	$\frac{1}{12}$	
60 0	5 6	$\frac{1}{8}$	58	—	—	
60 0	5 6	$\frac{1}{8}$	60	12	$\frac{1}{18}$	
60 0	5 6	$\frac{1}{2}$	19	25	$\frac{1}{18}$	
60 0	5 6	$1\frac{1}{8}$	16	40	$\frac{1}{12}$	
60 0	5 6	1	16	18	$\frac{1}{15}$	
60 0	5 6	$\frac{1}{2}$	16	18	$\frac{1}{15}$	
60 0	5 6	$\frac{1}{2}$	18	—	—	Blank pipe.
60 0	5 6	$\frac{1}{4}$	25	—	—	Blank pipe.
60 0	3 6	1	7	—	—	Blank pipe.
60 0	3 6	1	11	45	$\frac{1}{12}$	
40 0	4 10	1	20	—	—	Blank pipe.
40 0	4 10	1	25	25	$\frac{1}{12}$	
40 0	4 10	$\frac{1}{2}$	27	25	$\frac{1}{12}$	
40 0	4 10	$\frac{1}{4}$	—	—	—	Beat one stroke only and stopped.
40 0	4 10	$\frac{1}{4}$	53	9	$\frac{1}{18}$	
40 0	2 10	$\frac{1}{4}$	34	6	$\frac{1}{18}$	
40 0	2 10	$\frac{1}{8}$	14	—	—	Would not work with jet.
40 0	2 10	1	13	—	—	Blank pipe.
40 0	2 10	1	13	6	$\frac{1}{18}$	
30 0	5 4	1	28	—	—	Blank pipe.
30 0	5 4	1	29	20	$\frac{1}{12}$	
30 0	5 4	1	32	20	$\frac{1}{18}$	
30 0	5 4	$\frac{1}{2}$	32	—	—	Fluctuated in number of beats. Erratic in its beats. Sometimes very slow and then fast; altering its beat irregularly.
30 0	5 4	$\frac{1}{2}$	37	—	$\frac{1}{18}$	Height unknown, but very high; into quite a spray.
30 0	5 4	$\frac{1}{2}$	30	—	$\frac{1}{12}$	Ditto, as above.
30 0	5 4	$\frac{1}{4}$	91	—	$\frac{1}{18}$	Ditto, ditto.
30 0	5 4	$\frac{1}{4}$	65	—	—	Blank pipe.
30 0	5 0	1	27	27	$\frac{1}{12}$	
30 0	5 0	1	30	27	$\frac{1}{12}$	
30 0	5 0	1	27	—	—	The water in trunk regurgitated or rebounded fully 6in. and repulsed the hand at the inlet of the trunk or drive pipe. It could also be seen running or swinging back for 6in. at the beat valve. Blank pipe.
30 0	5 0	$\frac{1}{4}$	85	—	—	This was 80, 90, and then 85 beats. Blank pipe.
30 0	5 0	$\frac{1}{16}$	95	—	—	
30 0	5 0	$\frac{1}{2}$	3 to 35	—	—	Fluctuated in number of beats.
30 0	5 0	1	27	—	—	Regurgitated fully 9in.
30 0	5 0	1	30	27	$\frac{1}{12}$	
30 0	5 0	1	32	—	$\frac{1}{18}$	When the valve was working upright the bac water prevented the regurgitatior but by just tilting the valve ou right the water could be seen t fully 6in.

HYDRAULIC RAM BEAT VALVE TABLE—*continued.*

Length of Trunk. ft.	in.	Fall. ft.	in.	Length of Stroke of Bea: Valve. Inch.	Valve Beats per 30 Seconds.	Height of Jet thrown. Feet.	Size of Jet. Inch.	REMARKS.
30	0	5	0	½	39	—	$\frac{1}{16}$	No apparent regurgitation when upright, but strongly seen when slanted.
30	0	5	0	½	36	—	$\frac{1}{12}$	
30	0	5	0	½	32	—	—	No perceptible regurgitation, but slanting 5in. draw back.
30	0	5	0	¼	41	—	—	
30	0	5	0	⅛	210	6	$\frac{1}{200}$	Each of these jets could be distinctly seen, and if finger was held just over the jet it felt like the point of a needle penetrating.
30	0	5	0	½	37	—	$\frac{1}{16}$	
30	0	5	0	½	32	—	$\frac{1}{16}$	This was with the beat valve slanting, when there was about 12in. regurgitation.
30	0	3	4	½	19	—	$\frac{1}{12}$	Jet so high to be unknown.
30	0	3	4	1	16	—	$\frac{1}{12}$	
30	0	3	4	¼	60	—	$\frac{1}{16}$	With large jet would not work.
30	0	3	0	1	15	—	—	Regurgitation 12in.
30	0	3	0	1	18	6	$\frac{1}{16}$	
30	0	3	0	1	19	28	$\frac{1}{12}$	
30	0	3	0	½	17	—	—	
30	0	3	0	½	17	—	$\frac{1}{12}$	Considerable water loss.
30	0	3	0	½	—	—	$\frac{1}{16}$	Only made three to four strokes and stopped.
30	0	3	0	½	17	25	⅛	
30	0	3	0	1	—	—	—	Only made four or five strokes and stopped.
30	0	3	0	¼	56	—	—	
30	0	3	0	¼	57	—	$\frac{1}{16}$	Will not work with larger jet.
30	0	5	0	¼	109	—	—	Will not work with a larger jet than $\frac{1}{16}$th in.
20	0	5	0	¼	180	—	—	
20	0	5	0	⅛	47	—	—	Will not work with jet above $\frac{1}{16}$th in.
20	0	5	0	1½	38	—	—	
20	0	5	0	1	43	—	$\frac{1}{16}$	
20	0	5	0	1	49	20	$\frac{1}{12}$	
20	0	3	0		180	—	—	
20	0	3	0	½	66	—	—	
20	0	3	0	¼	28	—	—	
20	0	3	0	⅛	—	—	—	Would not work with jet larger than $\frac{1}{12}$th in.
20	0	3	0	¾	30	—	$\frac{1}{16}$	Stopped after twenty-six beats; no perceptible pressure at jet.
20	0	3	0	¾	24	—	—	
20	0	3	0	1	24	—	—	
20	0	3	0	1	27	—	$\frac{1}{16}$	
20	0	3	0	1	24	20	$\frac{1}{12}$	
10	0	5	0	½	250	—	—	Worked only ¼ minute and stopped.
10	0	5	0	½	140	—	—	Would not work with jet larger than $\frac{1}{12}$th in.
10	0	5	0	⅛	72	—	—	
10	0	5	0	⅛	68	—	$\frac{1}{16}$	
10	0	5	0	⅛	80	—	$\frac{1}{12}$	
10	0	5	0	¾	63	—	—	
10	0	5	0	¾	60	—	$\frac{1}{16}$	
10	0	5	0	¾	68	10	$\frac{1}{12}$	
10	0	5	0	1	60	—	—	
10	0	5	0	1	61	—	$\frac{1}{16}$	
10	0	5	0	1	61	8	$\frac{1}{12}$	
10	0	3	0	1	38	—	—	
10	0	3	0	1	35	—	$\frac{1}{16}$	Very irregular beat, and stopped several times.
10	0	3	0	1	41	10	$\frac{1}{12}$	
10	0	3	0	¼	38	—	—	
10	0	3	0	¼	43	—	$\frac{1}{16}$	
10	0	3	0	¼	46	—	$\frac{1}{12}$	
10	0	3	0	¼	43	—	—	
10	0	3	0	¼	42	8	$\frac{1}{12}$	Will not work with smaller jet.
10	0	3	0	¼	88	—	—	
6	0	4	0	¼	150	—	—	
6	0	4	0	¼	168	—	$\frac{1}{16}$	

HYDRAULIC RAM BEAT VALVE TABLE—*continued.*

Length of Trunk.		Fall.		Length of Stroke of Beat Valve.	Valve Beats per 30 Seconds.	Height of Jet thrown.	Size of Jet.	REMARKS.
ft.	in.	ft.	in.	Inch.		Feet.	Inch.	
6	0	4	0	$\frac{1}{4}$	—	—	—	Will not work with jet.
6	0	4	0	$\frac{1}{2}$	89	—	$\frac{1}{16}$	
6	0	4	0	$\frac{1}{2}$	92	—	$\frac{1}{12}$	
6	0	4	0	1	78	—	$\frac{1}{12}$	
6	0	4	0	1	78	—	$\frac{1}{16}$	
6	0	4	0	1	74	—	—	
1	6	3	0	1	69	—	—	
2	0	3	0	1	82	—	—	With beat valve nearly horizontal, worked very irregular.
2	0	2	9	1	60	—	—	
2	0	3	4	1	74	—	—	
2	0	3	4	1	64	10	$\frac{1}{16}$	
2	0	3	4	1	71	16	$\frac{1}{12}$	
2	0	3	4	$\frac{3}{4}$	89	18	$\frac{1}{12}$	
2	0	3	4	$\frac{3}{4}$	69	10	$\frac{1}{16}$	
2	0	3	4	$\frac{1}{2}$	86	10	$\frac{1}{16}$	
2	0	3	4	$\frac{1}{2}$	93	12	$\frac{1}{12}$	
2	0	3	4	$\frac{1}{2}$	98	—	—	
2	0	3	4	$\frac{1}{2}$	100	16	$\frac{1}{8}$	
2	0	3	4	1	88	16	$\frac{1}{8}$	
2	0	3	4	$\frac{3}{4}$	88	16	$\frac{1}{8}$	Worked very irregular.
2	0	3	4	$\frac{1}{4}$	154	—	—	Would not work with jet.
2	0	3	4	$\frac{1}{8}$	206	—	—	
3	0	2	5	1	60	—	—	
3	0	2	5	1	58	—	$\frac{1}{16}$	Very irregular in action.
3	0	2	5	1	60	—	$\frac{1}{12}$	
3	0	2	5	1	66	12	$\frac{1}{8}$	
3	4	2	0	1	50	—	—	
3	4	2	0	1	56	10	$\frac{1}{16}$	Beat irregular, with a kind of tick, tack; tick, tack.
3	4	2	0	1	54	13	$\frac{1}{12}$	Ditto, as above.
3	4	2	0	1	63	—	$\frac{1}{8}$	Ditto, ditto.
4	2	1	6	1	40	—	—	
4	2	1	6	1	42	—	$\frac{1}{16}$	
4	2	1	6	1	40	—	$\frac{1}{12}$	
4	2	1	6	1	45	—	$\frac{1}{8}$	
5	2	1	0	1	20	—	—	
5	2	1	0	1	—	—	—	Two beats and stops.
5	2	1	0	1	25	—	$\frac{1}{12}$	
5	2	1	0	1	25	6	$\frac{1}{8}$	
5	2	1	0	$\frac{1}{2}$	22	—	—	
5	2	1	0	$\frac{1}{2}$	—	—	$\frac{1}{16}$	Beat twice only.
5	2	1	0	$\frac{1}{2}$	—	—	$\frac{1}{12}$	Beat three times only.
5	2	1	0	$\frac{1}{2}$	31	—	$\frac{1}{8}$	Very regular beat.
5	2	1	0	$\frac{1}{4}$	45	—	—	Will not work with jets.
4	10	0	6	$\frac{1}{4}$	28	—	—	
4	10	0	6	$\frac{3}{4}$	—	—	—	The valve danced up and down but would not close.
4	10	0	6	1	16	—	—	The cause of the valve beating was owing to the valve going down to the reduced part of the socket at K, Fig. 959*.
4	10	0	6	$\frac{1}{2}$	—	—	—	Worked only three beats.
4	10	0	6	$\frac{3}{8}$	10	—	—	
4	10	0	6	$\frac{1}{4}$	38	—	—	
4	10	0	6	$\frac{1}{8}$	158	—	—	
5	0	0	4	$\frac{5}{32}$	74	—	—	Beat irregularly.

Remarks.—By altering the fall when the beat valve was at work, by gradually lifting the valve part of the 1 the beat becomes slower and slower till it ceases beating, and according to the height lifted.

HYDRAULIC RAM BEAT VALVE TABLE—*continued.*

Length of Trunk. ft.	in.	Fall. ft.	in.	Length of Stroke of Beat Valve. Inch.	Valve Beats per 30 Seconds.	Height of Jet thrown. Feet.	Size of Jet. Inch.	REMARKS.
30	0	5	0	½	39	—	1/18	No apparent regurgitation when upright, but strongly seen when slanted.
30	0	5	0	½	36	—	1/12	No perceptible regurgitation, but slanting 5in. draw back.
30	0	5	0	½	32	—	—	
30	0	5	0	¼	41	—	—	
30	0	5	0	⅛	210	6	1/200	Each of these jets could be distinctly seen, and if finger was held just over the jet it felt like the point of a needle penetrating.
30	0	5	0	½	37	—	1/18	This was with the beat valve slanting, when there was about 12in. regurgitation.
30	0	5	0	½	32	—	1/18	
30	0	3	4	½	19	—	1/12	Jet so high to be unknown.
30	0	3	4	1	16	—	1/12	
30	0	3	4	¼	60	—	1/18	With large jet would not work.
30	0	3	0	1	15	—	—	Regurgitation 12in.
30	0	3	0	1	18	6	1/18	
30	0	3	0	1	19	28	1/12	
30	0	3	0	½	17	—	—	
30	0	3	0	½	17	—	1/12	Considerable water loss.
30	0	3	0	½	—	—	1/18	Only made three to four strokes and stopped.
30	0	3	0	½	17	25	⅛	
30	0	3	0	1	—	—	—	Only made four or five strokes and stopped.
30	0	3	0		56	—	—	
30	0	3	0	¼	57	—	1/18	Will not work with larger jet.
20	0	5	0	¼	109	—	—	Will not work with a larger jet than 1/24th in.
20	0	5	0	¼	180	—	—	
20	0	5	0	½	47	—	—	Will not work with jet above 1/24th in.
20	0	5	0	1½	38	—	—	
20	0	5	0	1	43	—	1/18	
20	0	5	0	1	49	20	1/12	
20	0	3	0		180	—	—	
20	0	3	0	½	66	—	—	
20	0	3	0	¼	28	—	—	
20	0	3	0	¼	—	—	—	Would not work with jet larger than 1/50th in.
20	0	3	0	¾	30	—	1/18	Stopped after twenty-six beats; no perceptible pressure at jet.
20	0	3	0	¾	24	—	—	
20	0	3	0	1	24	—	—	
20	0	3	0	1	27	—	1/18	
20	0	3	0	1	24	20	1/12	
10	0	5	0	½	250	—	—	Worked only ¼ minute and stopped.
10	0	5	0	¼	140	—	—	Would not work with jet larger than 1/100th in.
10	0	5	0	¼	72	—	—	
10	0	5	0	¼	68	—	1/18	
10	0	5	0	¼	80	—	1/12	
10	0	5	0	¾	63	—	—	
10	0	5	0	¾	60	—	1/18	
10	0	5	0	¾	68	10	1/12	
10	0	5	0	1	60	—	—	
10	0	5	0	1	61	—	1/18	
10	0	5	0	1	61	8	1/12	
10	0	3	0	1	38	—	—	
10	0	3	0	1	35	—	1/18	Very irregular beat, and stopped several times.
10	0	3	0	1	41	10	1/12	
10	0	3	0	¾	38	—	—	
10	0	3	0	¾	43	—	1/18	
10	0	3	0	¾	46	—	1/12	
10	0	3	0	½	43	—	—	
10	0	3	0	½	42	8	1/12	Will not work with smaller jet.
10	0	3	0	¼	88	—	—	
6	0	4	0	½	150	—	—	
6	0	4	0	½	168	—	1/18	

HYDRAULIC RAM BEAT VALVE TABLE—*continued.*

Length of Trunk.	Fall.	Length of Stroke of Beat Valve.	Valve Beats per 30 Seconds.	Height of Jet thrown.	Size of Jet.	REMARKS.
ft. in.	ft. in.	Inch.		Feet.	Inch.	
6 0	4 0	$\frac{1}{4}$	—	—	—	Will not work with jet.
6 0	4 0	$\frac{1}{2}$	89	—	$\frac{1}{16}$	
6 0	4 0	$\frac{1}{2}$	92	—	$\frac{1}{12}$	
6 0	4 0	1	78	—	$\frac{1}{12}$	
6 0	4 0	1	78	—	$\frac{1}{16}$	
6 0	4 0	1	74	—	—	
1 6	3 0	1	60	—	—	
2 0	3 0	1	82	—	—	With beat valve nearly horizontal, worked very irregular.
2 0	2 9	1	60	—	—	
2 0	3 4	1	74	—	—	
2 0	3 4	1	64	10	$\frac{1}{16}$	
2 0	3 4	1	71	16	$\frac{1}{12}$	
2 0	3 4	$\frac{3}{4}$	80	18	$\frac{1}{12}$	
2 0	3 4	$\frac{3}{4}$	69	10	$\frac{1}{16}$	
2 0	3 4	$\frac{1}{2}$	86	10	$\frac{1}{16}$	
2 0	3 4	$\frac{1}{2}$	93	12	$\frac{1}{12}$	
2 0	3 4	$\frac{1}{2}$	98	—	—	
2 0	3 4	$\frac{1}{2}$	100	16	$\frac{1}{8}$	
2 0	3 4	1	88	16	$\frac{1}{8}$	
2 0	3 4	$\frac{3}{4}$	88	16	$\frac{1}{8}$	Worked very irregular.
2 0	3 4	$\frac{1}{2}$	154	—	—	Would not work with jet.
2 0	3 4	$\frac{1}{8}$	206	—	—	
3 0	2 5	1	60	—	—	
3 0	2 5	1	58	—	$\frac{1}{16}$	Very irregular in action.
3 0	2 5	1	60	—	$\frac{1}{12}$	
3 0	2 5	1	66	12	$\frac{1}{8}$	
3 4	2 0	1	50	—	—	
3 4	2 0	1	56	10	$\frac{1}{16}$	Beat irregular, with a kind of tick, tack; tick, tack.
3 4	2 0	1	54	13	$\frac{1}{12}$	Ditto, as above.
3 4	2 0	1	63	—	$\frac{1}{8}$	Ditto, ditto.
4 2	1 6	1	40	—	—	
4 2	1 6	1	42	—	$\frac{1}{16}$	
4 2	1 6	1	40	—	$\frac{1}{12}$	
4 2	1 6	1	45	—	$\frac{1}{8}$	
5 2	1 0	1	20	—	—	
5 2	1 0	1	—	—	—	Two beats and stops.
5 2	1 0	1	25	—	$\frac{1}{12}$	
5 2	1 0	1	25	6	$\frac{1}{8}$	
5 2	1 0	$\frac{1}{2}$	22	—	—	
5 2	1 0	$\frac{1}{2}$	—	—	$\frac{1}{16}$	Beat twice only.
5 2	1 0	$\frac{1}{2}$	—	—	$\frac{1}{12}$	Beat three times only.
5 2	1 0	$\frac{1}{2}$	31	—	$\frac{1}{8}$	Very regular beat.
5 2	1 0	$\frac{1}{4}$	45	—	—	Will not work with jets.
4 10	0 6	$\frac{1}{4}$	28	—	—	
4 10	0 6	$\frac{3}{4}$	—	—	—	The valve danced up and down but would not close.
4 10	0 6	1	16	—	—	The cause of the valve beating was owing to the valve going down to the reduced part of the socket at K, Fig. 959*.
4 10	0 6	$\frac{1}{4}$	—	—	—	Worked only three beats.
4 10	0 6	$\frac{1}{4}$	10	—	—	
4 10	0 6	$\frac{1}{4}$	38	—	—	
4 10	0 6	$\frac{1}{8}$	158	—	—	
5 0	0 4	$\frac{1}{32}$	74	—	—	Beat irregularly.

REMARKS.—By altering the fall when the beat valve was at work, by gradually lifting the valve part of the pipe, the beat becomes slower and slower till it ceases beating, and according to the height lifted.

Experiments—Water-hammer.

Pipe No. 1.—This pipe was split near one end, for a distance of 15in., along the line of the weld. When placed in the proving-machine, it bore the applied pressure until it attained an intensity of 400lbs. per square inch, when the split suddenly extended about ten inches; the pressure could no longer be kept up, and the test terminated.

The pipe was then taken to a pipe-cutting machine, and the injured part cut off. It was then again subjected to pressure. It bore a pressure of 1,100lbs. per square inch—the highest that it was convenient or customary to apply to that size—and was taken out sound.

Pipe No. 2.—This length was cracked for a distance of 15in. along the line of the weld, not far from the middle of its length. The crack had opened a little and the pipe was slightly bulged. This piece bore 300lbs. and then gave way, the fracture extended just enough to let off the pressure.

At the opposite end of the pipe was another split, 8in. in length. The part just fractured was cut off, and the remaining portion again subjected to the water pressure. This time it bore 1,050lbs. per square inch, when the crack was started and ran about 15in. It began leaking, and showed plainly the effect of the pressure at about 800lbs.

This was an unusually interesting specimen, as the pipe had been bulged considerably by the water-hammer along the line of the 8in. crack. The pressure afterwards borne, therefore, seemed to be likely to be a fair measure of that produced originally by the water-hammer. Such bulging as was here seen never occurs at usual pressures. The new break did not follow the weld, but ran irregularly, and apparently indifferently, through weld or solid iron.

Pipe No. 3.—This length was split for a distance of 22in., the end of the break being about 3ft. from the end of the pipe. It sustained a pressure of 250lbs. The sound part of the pipe was then tested up the 1,050lbs. without injury.

Pipe No. 4.—This piece was split, like the last, and to just about the same extent, was tested similarly, and gave way at 300lbs. per square inch.

All of this pipe was 8in. pipe, ⅜in. thick, and made with the usual form of lap-welded joint. The welds were not always perfect, as is probably the fact with all such pipes; but this pipe, butt-welded, would have borne very much higher pressures than those to which it was subjected in ordinary work by the steam carried on the line. It cannot be asserted that these lengths of pipe did not split under pressures less than those to which they were afterwards subjected, as it is very possible that the first blow may have found a weak part in the pipe, and the split may, in some cases, have extended to stronger portions. Nevertheless, it is possible that this was not the case in all instances, for in one case at least—that of the 8in. crack, which was accompanied by a decided bulge in the pipe—the water pressure, at the test, was, at least approximately, equal to, and very likely to have exceeded, those obtained at the later test.. It seems very certain that we may consider it as proven that the pressure produced by water-hammer is often enormously in excess of that familiar to us in the use of steam, and it has in many cases exceeded 1,000lbs. per square inch. It is, then, evident that it is not often safe to calculate upon meeting these tremendous stresses by weight and thickness of metal, but that we must rely principally, if not solely, upon complete and certain drainage of the pipe at all times as the only means of safely handling steam in long pipes, such especially as are now coming into use in the heating of cities by steam, led through the streets in underground mains.

The facts here presented have something of a revelation and possess unusual interest and importance to a workman using steam under such conditions as are here referred to. It is a fact, which has long been well known, that these suddenly produced pressures are often very great, and occasionally serious and sometimes fatal accidents due to this cause; but that these stresses are often as great as is here indicated has probably been little realised.

Also see Heating Water by Steam and Injector as a Preventative to Water Hammer.

TOWN WATER AND OTHER SUPPLY, ANCIENT AND MODERN.

I have now come to that part of my work which will treat upon the water supplied by private springs, water courses, and water companies. Such supplies are generally obtained from springs, rivers, streams, wells, and such like places, sometimes filtered through filter beds, as first supposed to be adopted by the Chelsea Water Works Company in 1829, and then consisting of from 15in. to 24in. of fine sand resting on two or three feet of coarse gravel graduating in size from that of a split pea to the size of a hen's egg. Also see Filters in Vol. I.

In order to form some idea of the origin of this water supply it will be necessary to give a brief outline of aqueducts of old, because they were in existence hundreds, or even thousands of years before they were adopted in England. The ruins of the aqueducts constructed with the supply from the Nile and also in Palestine, in the reign of King Solomon, the remains of which are to be seen to-day, excite admiration. Some of these extended at least from forty to sixty miles of covered stone channels, by means of arcades over wide and deep valleys, even through tunnels miles through the solid rock, and terminating into cisterns or reservoirs of the same material. These acqueducts were known by different names, such as Aqua Appia, Aqua Martia, Aqua Julia, Aqua Tepula, Aqua Virgina, Aqua Claudia, &c. As before remarked, some of these were running through channels, and over as many as half-a-dozen high arches, one above the other, viaduct fashion, often to a height of from 70ft. to 150ft.

The aqueduct of New Anio was constructed upon a continuous series of arches 6½ miles in length; many were 100ft. high.

Aqua Martia was 38 miles long, and had 7,000 arches.

Flascala, we are told, had an abundance of baths and fountains, and every house in Zempoala had water, also that Teycuco had an aqueduct from which every house was well supplied by leaden pipes, also Iztaclapa, with its thousands of houses, had water pipes, as we have to-day.

Aqueducts were first in this country constructed in the year 1760, by the Duke of Bridgwater, at Barton Bridge Canal, 39ft. above the surface of the river Irwell. It consists of three arches, the span of the middle one being 63ft. Many parts of Syria contain aqueduct remains. Aqueduct remains are also to be seen at Tyre, undoubtedly built 1,000 years before the Christian era. Yet we boast of the simple and insignificant work of the New River, date about 1612, but this was a simple aqueduct or uniform canal, which, instead of boldly passing over valleys and through hills (as did the olden Roman conduits) it crawls and creeps snake-like miles out of the way, and the wonder to me is how English people could make so much fuss of a person like Hugh Myddelton. Certainly, there was no skill displayed in his work, compared with the talents of the engineers over thousands of years before Myddelton was born. It would be tiresome to worry you upon these ancient viaducts and canals, so that we will come a little nearer home and see what has been done, by way of supplying water through leaden and iron pipes. The former thousands, whilst the latter are only hundreds of years old.

Good water, our chief object of research was then, as is now, of vital importance, and the quality is one of the first things that even a savage looks out for when settling in a new colony.

Now, this part of England, London (and by far not the oldest name of which we know anything of about this city), was originally intersected by many streams or small rivulets of the most interesting character, which we are warranted in thinking were of the purest type. On the banks of these rivulets the people naturally collected, and in due time formed their habitations, and made the then splendid crystal and pure tidal River Thames a convenient highway. This river would enable them to send (they being great hunters) their skins, ivory, and other goods away. It would also enable them in return to bring necessary stores for their consumption, and in due time they formed tow-paths on these banks. Later the place became colonized, and therefore the streams not being protected became fouled; necessity calling for the same *to* be covered over or filled up, and, as is now, roads were formed above them or in their places.

London Water and People.

We will now see what records we have of this London, and the first I find is, that the name of London was first called New Troy for many ages; but this at last became corrupted, and called Trinovant, also Trinoantes. When Lud, brother of Cassibellaum, came here, the acknowledged and best part of the town was on the Surrey and Kentish side; but when he obtained the government he shifted over to the Middlesex side, where he built what is, or what was then known as, London Wall, with towers and gates. He then changed the name to Caer.

Lud or Luds-Town. After this another change of name took place, when it was called Caer-London, and after it had been conquered by foreigners, they changed the name into Londreds, which signifies a fable stuffed with monstrous, ridiculous impossibilities, which is now scattered to the winds. Hence the use of the old and then worn-out title of the Griffin as a device to the City. We learn a lot about London from the celebrated Julius Cæsar's direct writings. He says: "I met with many difficulties in landing, occasioned partly by the great depth of the water drawn by the ships, which prevented their access to the shore; and partly by the heavy armour wherewith the soldiers were loaded, which rendered them incapable of engaging with the waves and the enemy at the same time, especially in a place to which they were entire strangers. Whereas the Britons, either by remaining on the land, or advancing a short way, they could commodiously throw their darts and bodily advance with their cavalry to prevent the enemy from landing."

But enough of this, and let us proceed with our water work until more history is required to expound the law relating to watercourses, springs and conduits.

Almost from the first settlement of the ancient Britons, and up to about 200 years after the time of William the Conqueror, the City of London was supplied with water by four rivers. First, in order, let us take that of Lang Bourne (or stream), which ran down or through the City, supplying the east part, and through what is now known as Fenchurch Street and Lombard Street; this turned at St. Mary Woolnoth, passed down Sharebourne Lane, and on to the Thames. This took its name from the long straggling length thereof. I may first here remark that I shall only now localize the conduits, &c., and give explication after

WALBROKE BOURNE.

Walbroke was a bourne, so-called from the London Wall, which it entered, and was like the former, but Walbrook was where now Broad Street is. It passed through Throgmorton Street, then in front of Lothbury Old Church, and about the centre of the present road; it then turned round near St. Mildred's Court, then through Walbrook, and from there into the Thames. This supplied the west part of the City.

RIVER OF WELLS.

There was the River of Wells, Turnmill Stream (so known on account of the waterwheels therein then fixed for working pumps), better known as Fleet Dyke, which ran down what is now known as Farringdon Street, but on the Fleet Street side, and passing Fleet Street to the Thames. This at one time was a magnificent large brook of pure water.

THE OLD BOURNE (HOLBORN).

Then there was the Old Bourne, now known as Holborn, a very prolific place for springs, also abounding Hatton Garden. The Old Bourne had its rise and course from what is now Holborn Bars and Hatton Garden. It flowed to the River of Wells, near Holborn Bridge, now the Viaduct.

There was Bayswater Bourne, River Lea, the Wandle, the Brent, Lea in Kent, and the Raven River, Deptford (which was 50 yards wide).

The Wiscombe Park Vanburgh, near Greenwich Park. This was about 500 yards from Maze Hill.

Battersea had a powerful stream which worked flour mills, and ran by Sleford House.

BAGNAGGE WELL.

Besides all these bournes there were a large number of springs or wells, such as Bagnagge Wells, on the site where Clerkenwell Police Court now stands.

HANOVER SQUARE.

There is an old well on the south by south-east part of the garden, which was there before the square was formed. There is now plenty of good water therein, which they use for the watering of the garden to this day.

There was also one on the north by north-east side of the square. Pumps were close to the rails, and the south side pump remains intact. I see the cabmen occasionally use it for their wash-leathers; they say it is softer than the ordinary water company's supply, which appears strange, considering it to be a natural spring.

HOLY WELL.

Holy Well rose just on the north side, and about half way up what is now called Holywell Street, Strand, or between St. Clement's Dane and Newcastle Street.

There was Clement's Well, which was on the green, in front of the present new Bankruptcy Buildings, and where the old houses, which were pulled down for the present new green, stood. Sadler's Wells in 1750 was a farmhouse with wells of splendid drinking water by the side, surrounded with poplars and elm trees, the wells being a kind of square pond with wooden rails all round.

THE STRAND WELL.

The Strand well is now covered over, but still remains with water therein. This is situated about the centre of the road and about the middle of the wall of St. Mary-le-Strand. There is a tablet in the church wall which runs thus: The pump well is XIX. ft. south from this stone and VIII. from the surface. Its diameter VII., and depth XXVIII. ft. Reopened and a pump erected Anno Domini MDCCCVII. William Holmes, Thomas Harper, Churchwardens.

THE CONDUIT AT PENTONVILLE.

This was once a popular place of amusement, from which White Conduit derives its name. It was built about 1641 at the back of 10, Penton Street, at the corner of Edward Street. This conduit supplied Carthusian Friars. There was also a small conduit at the back of White Conduit Gardens, near Warren Street, where Huntingdon the preacher, known as the "Sinner saved," used to take great interest in it to keep it clean, &c., mixing his cleanliness with Godliness.

There was also, up to within this last thirty years, Clerk's Well, or Clerkenwell, when I knew it. It was curbed square with a kind of hard Bath stone, and was situated just outside the rails on the west end part of the churchyard, with a public-house right opposite, where the bell-ringers used to meet. The said church took its name from this well, before the Parish (Church) Clerks' Company was chartered, somewhere about the date 1600. This company of Amen Clerks made a rule of assembling there yearly, and to play some part of scriptural history. For example: in the year 1390, July 18th, the Skinners and Parish Clerks of London played interludes at Skinners' Well, which was near Clerk's Well, and the play continued for three days together, when Richard II. and the Queen, and many nobles were present. Also in the year 1409, in Henry IV.'s time, they played at Skinners' Well, which lasted eight days, their subject being the "Creation of the World," when many nobles and [illegible]. When plays were not acted, there [illegible], which also took place at St. [illegible] Fag's Well was at Smithfield, by the [illegible]. There was also what was called [illegible]" on the west of Smith- [illegible] of it being a noted place for [illegible]

[illegible] close to the parish [illegible]'s well [illegible]

well, square, curbed with stone, and called Dame Annis the Clear, and not far from it, westward, was another clear water well, known as Perilous, because youths used to get into it to bathe and were often drowned. The wells before recited were shallow wells. St. Pancras Wells were about 400 yards on the south side of St. Pancras Old Church. These wells had pumps, and the water was supposed to be a cure for everything.

REGENT'S PARK WATER.

This is a sheet of water 1,200 yards long, and about 140 yards in the widest part, with a T shaped branch of about 450 yards. There are six islands therein. There is also the Princes Reservoir, a sheet of water 600 yards long, by 90 yards wide.

BARROW HILL RESERVOIR.

This is 120 yards long by 50 yards wide, one of the most splendid positions for a reservoir in the suburbs of London.

ST. JOHN'S WOOD RESERVOIR.

These are four in number, the largest being 70 yards by 20 yards; their situation is near the Barracks.

KILBURN WELLS.

These form a nice little stream and conduit at Kilburn Wells, 130 yards long and 30 yards wide. Another one is by Kilburn Bridge, 80 yards by 20 yards. These used to empty into the Bayswater Rivulet, and partly formed The Tybourn.

HIGHGATE PONDS.

These ponds were eight in number, some much larger than others. Some still exist, but are not in use for domestic purposes.

STRAND LANE WELLS, AND OLD ROMAN BATH.

This is in the Strand, London, opposite Newcastle Street. This bath is about 60 yards down the lane on the east side, and under a little old-fashioned looking house, which stands between two large and newly-built warehouses. The house has iron rails in front, and about 5ft. of area, having an iron gate, with steps down and an old-fashioned door. This old building seems to have escaped the notice of most London historians, and therefore very little is known of it. I am informed that it was built in the time of Titus, but I should prefer to say Julius Cæsar. The ground upon which it stands was, if not now, belonging to the Danvers of Swithland, Leicestershire.

Having descended from the gate, and through the doorway four or five steps, you pass an arched passage, more like a cellar than anything else, and on the left is a doorway which leads you into a vaulted chamber 16ft. in length, 9ft. wide. The well or bath top, like a swimming bath, is level with the floor. This is 13ft. long, 6ft. wide, and 4ft. 6in. deep. The water is supplied by a spring, doubtless in conjunction or of the same veins as the old spring of Holywell Street, which was about 150 yards due north by north-east of this spot. The water is beautifully clear and good for drinking purposes, and runs at the rate of about 2,688 gallons per day. There is also under the same roof a splendid white marble bath, said to be built by the Earl of Essex (it should be here noticed that Essex Street is just by, where the Earl lived when in London) about the year 1588. The water seems to rise from the bottom of the upper bath or well, from where it appears the marble bath has its supply. It is curious that neither the sewer along the Strand, which is above, nor the [illegible]t Railway close by, and some 30ft. below this level, [illegible]ared with these springs.

THE OLD CONDUIT IN GREENWICH PARK.

This was built square with two gable ends all stone, and there was an excellent supply which ran considerably to waste so late as 1835. It was very much like King Henry VIII.'s conduit at Kensington, having about the same kind of supply. There are also springs breaking out at the foot of the sand hills between Greenwich and Woolwich, which flow across the marshes and into the Thames.

BETHNAL GREEN PONDS.

These were at Ramsey Street, St. Matthew's, Bethnal Green, and were of an L shape 80 yards from elbow to each point. The ponds were 140 yards by 100. The smaller one was 40 yards by 20, close to Elizabeth Street, Old Bethnal Green Road.

MILE END FISH POND.

This was near the Jews' Burial Ground, between Whitechapel and Mile End Old Town.

WEST HAM WATERWORKS RESERVOIR.

The situation of this is close to Mill Hill Road near the canal lock. Its shape is that of an oval, 80 yards by 40 yards.

HACKNEY ROAD.

There was a beautiful sheet of water 160 yards by 60 yards, by the side of Russia Lane, at the further end of Hackney Road.

WOLVERLY PLACE.

Here was a lovely piece of water 150 yards by 100 yards, called the Fish Pond. Another two sheets of water were at the Dove Row near the Gas Light Works, one 170 yards by 150 yards, and another 160 yards by 100 yards.

ROTHERFIELD STREET CONDUIT.

This was near the Old Lead Mills, and was 100 yards by 50 yards.

PEARLES POND, ST. LUKE'S, CITY ROAD.

This was near the burial ground, St. Luke's, at the back of the hospital, between Baldwin Street and Old Street. It was a splendid sheet of water 60 yards by 30 yards.

BAYSWATER, QUEEN'S ROAD CONDUIT, FORMERLY KNOWN AS BLACK MAN'S LANE.

Here stood a splendid crystal sheet of drinking water, which had its source of supply from the springs therein. Its situation was 320 yards north from the rails of the Kensington Gardens, and 30 yards from the road alongside. The size of this sheet was 90 yards from point to point, and 35 yards across the middle.

MOSCOW ROAD, BAYSWATER, CONDUIT.

This was situated 70 yards from Petersburgh Place, and 320 yards from Blackman's Lane. This was a sheet of pure water 40 yards long and 20 yards wide.

HOLLAND STREET PONDS, KENSINGTON.

There were two ponds north of Holland Street, near Observatory Avenue, or 100 yards from Hornton Street, and between Holland Street and Pitt Street. The largest was 50 yards long by 10 yards wide; the smallest 30 yards by 20 yards, of good drinking water.

GROVE HOUSE, UPPER KENSINGTON GORE.

This was a pond of pure water, 160 yards by 15 yards, which supplied Gore House and the grounds, &c., where now stands Lowther Lodge.

HOLLAND HOUSE WATER SUPPLY.

This is one of the oldest historic residences in Kensington, if not in London, and has been well supplied with water of natural springs suitable for such a building. I may remark that this old fabric takes its name from the first Earl of Holland, who was beheaded in 1649.

In the old kitchen, which is now disused and more like a barn for size, used to be a splendid spring, and there were a lot of other little ones on the north-east side of the building, which supplied the old moat, and on the south entrance side used to be a fountain close to the stepped bridge and entrance.

These springs used to flow down on the west side of the house and into the old fish ponds below Addison Road, where they emptied themselves into the creek. I believe this house now derives its water from the water company's pipes.

On the north of Holland House are other mansions, which, before the water company existed, obtained their water from the same veins.

HAMMERSMITH PONDS.

One of, if not, the largest, was situated at the back of Blythe Lane, known as the Ocean, about 440 yards by 300 yards, and very deep in some places. This was quite self supporting. The water was very clear, but had a peaty twang, probably owing to the neighbouring marshes which ran alongside of the creek, which creek then ran alongside of the present Addison Road Station, then a canal.

THE SEVEN STARS POND.

This is opposite the Seven Stars, Starch Green, Hammersmith. When I knew it forty years ago the water was fit to drink, but, latterly it has become a bathing place for dogs, and is therefore a nuisance to the neighbourhood; there is a strong talk of filling it up. It is about 33 yards by 20 yards.

STAMFORD BROOK, HAMMERSMITH.

Here was a splendid little stream of good drinking water forty years ago, but, like nearly all the others, has been ruined and covered up. This ran by the side of Stamford Brook Old Cottage, which at that spot gave the boundary line between Chiswick and Hammersmith. The said old cottage and ground (about a quarter of an acre) is still supplied by a pump and well water of great purity.

NORTH END ROAD PONDS, FULHAM.

From about where the cedars are, down to the District Railway Station, was a long narrow pond of good water fifty years ago, now built on. Fulham at one time, like Brentford and other places in the valley of the Thames, was noted for many overflowing artesian and other wells. This is accounted for in the natural wells, that there has at one time or other, been a disturbance in the stratas, and the fact that the level of the ground about the Thames valley is considerably lower than the points P T, Fig. 772; but as time ran on a general depression of the water level in London w[illegible], which will be proved from the

fact that in 1820 the chalk water in the City wells stood at Trinity high water mark. The depression of chalk water in the City of London amounted to (in 1840) 50ft., thus showing a depression or recedence of the water at the rate of 2ft. per annum. Nor does this rest with the chalk water alone, for there are other sources of excellent water which lay amongst the sand and gravel, and are generally to be found upon a saucer of clay, while sand is often as the chalk is, found bedded between two layers of impervious material, known as argillaceous drift deposit. See the lines F G and S O and G T and J T, Fig. 959A. F or J

FIG. 959A.

would be the place for taking in the water, the amount of which would depend upon the superficial area of sand, shingles, and other pervious substance, and the amount (if any) of bournes that may empty therein. Here you see the water would, like that through the chalk, naturally run to the lowest level, often running into great chasms or caves, as at Q, and finding an outlet as at S; but should this outlet be closed or bend up, through argillaceous drift to T or M, then, by sinking or boring, the water would rise up to this level, when you get what is known as an artesian well, from a stream of water other than chalk water. But it may so happen, as often it will, that you need only go a few feet through a layer of clay as at J, and if you go a little distance away, as at M, you will get a magnificent supply in the shape of a fountain. Wherever you get this water from, one thing is almost certain, that the outpour can only be equal to the intaking. For argument's sake; in these landsprings, as they are sometimes called, supposing you have an area of, say, ten acres, whereon rain-water falls, and you get this quantity into the before-mentioned saucer. Here would be a splendid supply, suitable for, say, a house and outhouses, and a lake with a clear little stream running to waste, as was some fifty years ago about the neighbourhood of Bayswater and other parts of London. But, suppose your ten acres to be built upon, and this water to be, as is in this case, caught by gutters and conveyed into sewers, can you expect your natural springs to flow as of old.

Then, again, there are the sewers and the underground railways, which have played havoc with these natural springs, and what with one and the other they are, as a matter of fact, gone. The above can be to-day illustrated at [illegible]. This town is situated on the southern slopes of the north downs, where the chalk is extremely narrow [illegible] half a mile wide, but up above and north [illegible] Tucksbury Hill, something like [illegible] one in breadth. This apex is [illegible] what we may call capped with [illegible]. There is a conduit or circular well about [illegible] the caught water flows, [illegible] main, and so the [illegible] good wholesome water at [illegible] gallons per day.

EARL'S COURT LANE, NOW EARL'S COURT.

Here was a splendid pond of water, from which the farm (which stood where Earl's Court Station now stands), was supplied, and also Earl's Court House, but which was on the opposite side of the road. This farm was known as Manor House Farm.

COLHERNE HOUSE, EARL'S COURT, NEAR BROMPTON ROAD.

Here was a reservoir with its natural springs, which was situated 80 yards from Brompton Road and near Walnut Walk, and nearly opposite the bottom of Earl's Court Road. It was 120 yards long by 25 yards wide, and supplied the mansion with its necessary water.

CROMWELL HOUSE, ALSO CALLED HALE HOUSE CONDUIT.

This conduit was situated half-way between Old Cromwell House (which stood where the south-west part of the South Kensington Museum now stands) and the public house known as the "Hoop and Toy." It supplied the whole of the water to Cromwell House and its belongings. I may here remark that many have tried to find this old conduit out, including the Kensington historians, Lyson and Falkner, and the collector Loftie.

SLOANE STREET CONDUIT.

This conduit was on the west side of Sloane Street, near Charlotte Cottages and Chapel Row. It was about 300 yards down Sloane Street from the Knightsbridge end, and 100 yards on the west of the street. Its size was 110 yards by 50 yards. Some people thought that this was fed by some natural outlet from Hyde Park Pools, now called the Serpentine, which to this day loses large quantities of water, although there are natural springs therein, but which are more towards the head. I have also been told that there are no springs in the Serpentine, but this is false, as I have seen many therein more than once or twice. Besides, these springs can be felt if you explore the Serpentine by swimming, the water being of a different temperature.

LEADER STREET RESERVOIR.

This was 50 yards from Leader Street and 250 yards from Marlborough Road, Chelsea. It was five-sided, and its size was 60 yards by 40 yards

VINCENT SQUARE POND.

This was in the playground for the Westminster scholars, Douglas Street, Rochester Row. It was 100 yards long by 30 yards across the centre. It was the shape of a right-angled triangle, as though made to fit in the corner of the square.

BLACK HORSE POND.

This was near Trundle Lane. It was 320 yards by 170 yards at one end, and 80 yards at the other.

MANOR HOUSE, KENNINGTON.

This reservoir was 380 yards from Walworth Road, and half-way between Manor Row and Harford Lane, at the back of Canterbury Place. It was 120 yards long and

90 yards wide, having a small island and three projections, like three Punch's noses; in fact, it used to be termed the kidney potato side. There was another the exact shape of a kidney close by, this was 80 yards from end to end, and 20 yards across the centre.

LAMBETH WALK CONDUIT.

This was situated 60 yards from Lambeth Walk, and 50 yards from the burial ground. It was 25ft. in diameter.

WIMBLEDON.

Here there are large quantities of water, which can be seen by the reader taking a walk round.

Croydon, Mitcham, Sydenham, Camberwell, Peckham Rye, and nearly all round the south of London, has been noted for its springs, and to prove the prolific nature or abundance of some of these springs, it will be sufficient to record that the springs of the south side of Peckham Rye Common at one time formed an important portion of the Grand Surrey Canal supply.

Alas! for many of the old springs and City bournes, with crystal streams, and the City wells! They, by process of time, encroachment of buildings, and heightening of the ground, are nearly all gone, and the Londoner forced to seek water elsewhere. The first part of this took place about the time of King Henry III., date 1237, when it was granted that the citizens and their successors, by one Gilbert de Sanford, be at liberty to convey water from Tyburn into the City. The mayor and commonalty of the City, the citizens at the time being partially deprived of their supplies, were glad to avail themselves of this alteration.

BAYSWATER CONDUIT (ORIGINAL).

Bayswater Conduit has for many years been of great interest to the citizens of London, owing to their positions being so very obscure, not one of the historians having deemed it necessary to point out their exact positions; in fact, there is no history which can be depended upon for the same, and it has given me an endless amount of trouble to discover their real positions, which, happily, there is now no question about.

Lead Pipes.

Water was attempted to be brought through six-inch leaden pipes, cast in Holland, which pipes proved a miserable failure, owing to the rotten condition of the

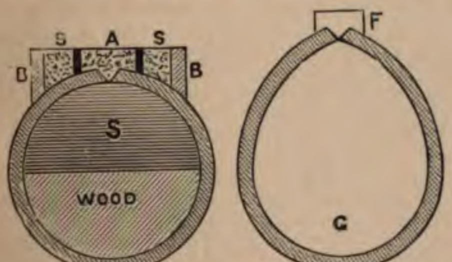


FIG. 959B.

material (an account of which will be hereinafter shown), which, happily, was discovered in time. The pipes were then made from cast sheet lead, half-an-inch thick, by British plumbers; much of this was sand burnt, as shown at Fig. 959B, whilst other portions were soldered. These pipes were in ten feet lengths, being connected with wiped and overcast joints of excellent shape, many of which I have seen.

In all, there were about four miles of this pipe made, and the expense of the undertaking was partially borne by the principal citizens. These pipes emptied themselves into conduits or lead cisterns, many encased within stone buildings, much after the style of the old Conduit House, Fig. 959C (of which more anon), and Fig. 959D, also

FIG. 959C.

Figs. 1,399, 1,408, 1,413, and 1,428. The first of these conduits was situated from Paddington to James Hed, at a distance of 2,805 yards; the next, from James Hed on the Hill to Mewsgate, was 561 yards; and from Mewsgate to the cross in Cheapside was 2,662 yards.

The history of the latter conduit is very amusing, for it is said that on the safe delivery of Queen Isabel (wife of King Edward II.), in the year 1312, of a son, who proved afterwards to be King Edward III., the conduit in Cheap instead of running water, was made to run with wine, and all was welcome to partake of the same.

The greatest of these conduits was erected on West Cheap, that is to say, the cross in Cheap, in the year 1285, Henry Wales being the mayor, when afterwards these conduits were increased to about twenty.

The cross in Cheap conduit was close to the old church of St. Michael's, West Cheap, where, on the above wine day, was fixed a pavilion, which was partially in the middle of the street, where a large vat of wine was placed, and all passers were invited to drink.

John Pope, a barber, of the City, by his will dated the 11th of May, 1437, gave to the mayor, chamberlain, ar commonalty of London for ever, property enough to ke the conduits in good repair. In the year 1401, the Tow

upon Cornhill had a cistern supplied by this water, so that the pipes were further extended, and spouts then called "bosses of the water" were placed about Billingsgate and Paul's Wharf, and by St. Giles' Church Without, Cripplegate; this was about the year 1423. Water was also conveyed to Newgate Gaol and Ludgate, in 1432. By-the-bye, it is very interesting to know that the Tonne, before-named, on Cornhill, was a prison, which they had no better use for than to convert it into a water cistern or conduit supplied from the TYBOURN PIPES, and on

FIG. 959D.

one side there was erected a cage with a pair of stocks over it, for punishing what was then called 'night walkers" (brawling drunkards of all classes), together with a pillory for paying back cheating bakers and thievish millers. But, in order that I may bring the historic parts in, and the law appertaining to this subject, it will be necessary to take one district of historic note into consideration, and, therefore, we will settle upon Kensington.

KENSINGTON IN THE HUNDREDS OF OSSULSTON.

Kensington appears to have had a good time of it if names are anything to boast of, for it seems to have had seven in all, perhaps no better reason for having swayed from one to seven, than the old woman's saying that there is "luck under the odd number," and the following is the medley:—First it was Chenesi, then Chenesitun (see *Domesday Book*), after Chensnetuna, then Kensitune, then Kinsintuna, then Kensintuna, and finally Kensington.

Here they appeared to have most superb water, and as this is now one of the most fashionable, yet one of the oldest, parts of London, and a place which beyond question is to be relied upon for its historic springs and water supply, I deem it necessary to record the following facts, which have taken me a considerable time and expense to fish up, because of the many absurd tales which have been recorded by well-known historical writers, all of which have doubtless copied or drawn on one another's imagination; and it is these writers that have caused me such an enormous amount of trouble to undo their knavish work, and to find the actual spots or sites where these wells, rivers, bournes, and conduits stood.

When the thievish Saxons were invited to protect this then troubled island they saw the value thereof and confiscated the same. This was about the year 448. Parts of the conquered country were divided by the general which was worth claiming, and these shares were again divided and sub-divided by and amongst the chiefs, who had put themselves under command, and by these means each tribe who was then worthy of position had some sort of independence.

The greater shareholders would constitute pagi or counties. Now the whole army was most likely subdivided into bands of 1,110 men each. The portion of land, springs, and rivers assigned to these several families constituted what was known as so many trythings, hundreds, and tythings (or thousands, hundreds, and tens), each under its own earlderman or acknowledged superior.

The lands, rivers, and springs which fell to the original successful warriors in the first allotments, may be regarded as bocland (bookland), and were possessed by these families on conditions free from all encumbrances, save and except the obligation to the community itself; bocland was truly allodial, viz., the totality of it was in the proprietor, and descended to his children.

Soon after the Norman Conquest (date 1066) these allodial proprietors resigned their possessions into the hands of the king, or some other nobleman, conditionally of receiving them back, under conditions known as Feudal service, thus obtaining the necessary protection of their landed property. Such was the distribution made by William the Conqueror, and this Chenesi Manor was allotted to the Bishop of Constance, which appears in the record of Domes-day, there to be held off in, by one Aubrey de Vere, one of the chieftains.

Now this land of Aubrey de Vere is rated, viz., pays danegeld for ten hides (a hide of land is 120 acres); the land is estimated at ten carucates (one carucate is what only one plough can cultivate), of which four carucates are in demesne, villans (villagers) having five ploughs. Twelve villans, each having one rod (or yard land) and six with three virgates or rods (a virgate is one quarter of a hide). The priest has half a virgate: there are then seven bondsmen or serfs.

Two carucates of pasture for the cattle of the town; pannage (runs and forest food) for 200 swine, and three arpents of vineyards. In the whole this was worth, when allotted, £6; but it increased to £10 in King Edward I.'s time, who held the manor, and had power to sell it.

You have seen how this and other manors came into the hands of individuals; you will also now soon see what all this historic work leads up to. It is to show you what [illegible] of their bounden duties. It was laid down as a [illegible]ed obligation when these lands were allotted, that

every landowner should protect all springs, water courses, bournes, conduits, and wells and give free access to his neighbour, and travellers of good report, for a sufficient supply to his wants, after the owner had secured enough for himself; and it is most stringently laid down that any one who disturbs these water courses, springs, or wells, is guilty of fiendish tricks, the penalty of which is to be *flogged* to *death*. (See account of Access to Lands.)

Now, as London increased in population, as before shown, the natural springs of Kensington and Paddington became of great value, not only for the supply of their own people, who were compelled by the law before recited to assist in supplying their neighbours, which is proved by the following account; but this will necessitate showing one or two more sketches, and for the present purpose I leap over a few hundred years, but will partially fill this lapse hereafter on the Springs and Conduits of Paddington and Bayswater.

A conduit was built about the year 1515 by King Henry VIII., said to be a bath, built for Queen Elizabeth when a child. Its situation was at the east end of Kensington New Barracks, just inside the further brick wall

FIG. 959E.

on the right and 120 yards from Silver Street, going through the passage, viz., from Silver Street towards the Palace. This old relic was knocked down about the year 1871, and a powder magazine built to its exact size on the old footings. It is about 12ft. by 9ft. square, and about 8ft. to 10ft. in height. Fig. 959E is a representation of the inside, but the outside of the roof was simply that of four gables in solid brickwork. This conduit or bath was supplied by a 2in. leaden pipe, as can be seen where the water runs in. This pipe comes from a natural spring, which was by the side of the kitchen garden, and near the garden wall, and Fig. 959F is an exact representation of

FIG. 959F.

the then covered-in spring. It is an erroneous idea that King Henry VIII. occupied Kensington Palace. I doubt whether he was ever in it; he certainly never was owner nor even occupier. It was not occupied by royalty until William III. purchased what was then known as Nottingham House from the Earl of Nottingham, on the 25th March, 1689. The building was a very old one at that time, but William III. made some grand alterations. He beautifully laid out (though in Dutch fashion) the grounds, and erected three fountains on the south side of the Palace. One of these fountains was situated about ten yards from the road, west of the gardens; another about twenty yards from Kensington Road, or at the south-west corner of the gardens, with a grand one near the bottom of the garden near the road, and right in front of the middle part of the Palace. These fountains were supplied from the tank in Fig. 959G. So much for the much-talked-of Kensington Palace being the residence of King Henry VIII. But we will now see what King Henry VIII. really did do, and give him the credit of building Fig. 959E.

Just below where the conduit or bath stood, is an old red-brick house, and it is said to be the house where Anne Boleyn lived, which I have good reasons to believe was Henry VIII.'s Kensington home. This old house is said to have been at one time supplied with water from the before-mentioned conduit. The old house referred to, now disused, stands about 60ft. back from the road, and is kept quite private; it stands next door to Thackeray's old house.

Henry VIII. being seized (possessed) of the Manor of Chelsea and Kensington, built a splendid mansion in Chelsea, and supplied this, his new building, with water through 3in. *square* soldered-up leaden pipes, with wiped joints from the before-mentioned bath or conduit. These pipes ran through the principal part of the moor (this part and just above the old barracks was then known as the Moor) and across the Kensington Road, by De Vere Gardens, and away to Chelsea Place.

In the year 1657 the before-mentioned house in Chelsea Place, with all its appurtenances, including the *Chelsea* conduit, were handed over to William Lord Douglas, and his wife Anne, Duchess of Hamilton, to Charles Cheyne, Esq., whose son, William Lord Cheyne, sold it in 1712 to Sir Hans Sloane (which may be seen from a bill filed in Chancery in 1702, by Lord Cheyne, against the

Duke of Beaufort, which proceedings were renewed by Sir Hans Sloane in 1716). It appears that the Beaufort family, also possessors of other large premises in that neighbourhood, and formerly the property of Sir Arthur Georges, had assumed ownership of the Chelsea conduit, which was fed by the conduit at Kensington. Not satisfied with all this, they threatened to deprive Lord Cheyne of the benefit thereof, but the Lord Chancellor decreed (October the 14th, 7 Geo. I.): "That the right in the said water of the Chelsea conduit was vested in the plaintiff" into the defendant's house, until the plaintiff's house and gardens were *without undue consumption supplied;* ' and notice this, that the plaintiff was entitled to the waste water. The defendant was ordered to do all repairs, and the cleaning of the springs, water courses, conduits at Kensington, and also the main pipes from Kensington to Chelsea conduit, and the pipes and cisterns in the same, except the pipe conveying water from the conduit in King's Road to the plaintiff's house, which was ordered to be repaired by the plaintiff.

Fig. 2090.

The house, which was occupied by the Bishop of Winchester, purchased by the Duke of Hamilton, was also supplied from this conduit. These are the material points or rights which were well understood as the government of small water works, water courses, springs, &c., and hold good to this day, excepting the capital punishment.

SHEPHERD'S FIELD CONDUIT.

Before I close, and to strengthen this point, I will append another account of these public property grabbers, which took place at the beginning of this century; at the same time it will record the whereabouts of the notable Shepherd's Field Conduit. This was situated at Hampstead Green Meadows, at the south-western corner of the village, near Church Row, but on the eastern side of the fields there lay an old conduit or shepherd's well, where you could have a drink of pure water free of charge, which stream doubtless had run thousands of years, and had supplied the inhabitants and poor people for ages past. So much they thought of this well that they protected it with an arch, and round the back part with rails; but in course of time this much cherished stream, to a certain extent, became confiscated, not this time by the water company, but by Lord Loughborough, who was living close by, and who descended to thievish tricks, and tried his utmost to stop the inhabitants from obtaining the water by *enclosing* the well; a very bold and saucy stroke of business. So great was the public indignation, that they pulled the enclosure down for the third time, when they took the hog by the ear to a court of law, where a decision, according to the old law, was justly given against Lord Loughborough, and so the well remained as of old. It is in Hone's Table Book much praised, the following being an extract:—"The arch embedded above and around by the green turf forms a conduit head to a beautiful spring, the specific gravity of the fluid, which yields several tons a day, is little more than distilled water.'

It is plain that such a source of supply must have been of great value to the inhabitants; but apart from this, I am informed that a few of the poor people made a living (though, probably, a scanty one) by carrying and selling buckets of this water at a penny each. Of course everyone knowing anything of springs, knows that it is least of all fresh water liable to freeze.

[illegible] converted only a *portion* of [illegible] pipes; but had he [illegible] would have been [illegible] institution); "but [illegible] apply for powers to [illegible] said pipes and [illegible] plaintiff should [illegible] of mending [illegible] supply of water [illegible] be any [illegible] to the [illegible] running

BAYSWATER AND TYBOURNE CONDUITS.

We have now come to the most difficult part of the water supply to authenticate, owing to the immense amount of simply journalistic rubbish that has been printed thereon, which has been much overdone, and more like fables than historic facts, even by would-be historians.

There appears to be something fascinating about these old Bayswater Conduits to the journalistic world, because they have appeared hitherto to have been able to concoct readable matter, which they could not historically obtain. Now I flatter myself that no one but those having been, at least, thirty or forty years searching in the trade, and by mixing up with the *old plumbers*, and waterworks' engineers, and joining as *working* members, and also consulting with members of the several institutions of which I am a member, could possibly have any chance of ascertaining the whereabouts of these once important sources.

PADDINGTON TO TYBOURNE WATER SPRING CONDUIT.

I will now point out the principal place from where the water ran to Tybourne. We will next examine this particular conduit head. Fig. 959c is a correct representation of this old spring, of which there were several in this quarter. The exact spot of this or the *original* one was about the middle of Conduit Place, about six yards on the south side, just where the new buildings now stand, and close to Spring Cottages, now known as Spring Place, in Spring Street. To make it quite plain and easy to find, it is just at the back of Praed Street Metropolitan Railway Station; but when the Grand Junction Water Works reservoirs, where now stands Talbot Square, were destroyed, this old landmark was also removed, and nothing now remains but the before-mentioned Spring Cottages.

PADDINGTON AND LONDON OLD CONDUIT.

NOTICE.—These names must not be confused, viz., Paddington to Tybourne; Paddington and London; Bayswater Conduit; as they were three separate and distinct sources, or beautiful springs, in the huge forest of Paddington, which name is not to be found in Domesday Book.

The exact position of the *original* Paddington and London Conduit was at the back of the St. George's burial ground, Bayswater Road. These springs used to overflow the ground, and run down by the north side of the Oxford Road, now Bayswater Road, and empty into the West Bourne. Here, date about 1200, the City of London people, who had poisoned and also converted the streams away, were driven to their wits' ends to know how to secure a good wholesome supply of water. They constructed a conduit house, which was supported by the Corporation of London, to preserve large springs. Anyone wanting to see such a spring should take the train down to Mitcham in Surrey, and examine the Raven spring, near the gasworks, which is about equal to the old Bayswater in purity, and gives about quarter the quantity of the Bayswater spring; and should you feel disposed to examine a spring of exact magnitude and purity, there is one at East Malling in Kent, which runs close to East Maliing Church, the spring head being about three-quarters of a mile up in the fields. These springs I should recommend anyone to examine, as all the writing in the world cannot describe the scene of such interesting places.

The *original* Paddington Conduit has been dreadfully misrepresented, for in many works of authority it is distinctly laid down "that it afforded a plentiful supply of water to London." The spring did yield more than they made their pipes to carry by half *to their intervening conduit*, their pipes being only 6in., and owing to the long distance, and being intercepted at the reservoir at the north side of Oxford Street, they did not avail themselves of the full amount of water which these pipes would have carried had they been continuously connected from Paddington to the City, which would have acted as a syphon with a long leg; in fact, the 6in. pipe running full bore would have taken as much as a 12in. pipe could have delivered from the conduit head into the intervening conduit, owing to the little fall of the first length of conduit pipe. This is proved by the fact that they, in a short time afterwards, sought powers to construct a second run of pipes, of which, more anon.

We read that there was an overplus from this original conduit head, which helped to supply the then pools in Hyde Park. I have already shown you the position and antecedents of several of the City conduits that were supplied by this 6in. pipe, and as there is a matter of some years to spare before anything further was done by providing a better, or to use many historians' words up to the present time, "that it afforded a *plentiful* supply to London" (the italics are mine), I will give you a general outline of the waters of Bayswater, which are somewhat interesting, not that I write from this point by any means, but for the purpose of usefulness to guard my readers against the fallacy of doing work twice over, of which this Bayswater conduit was a fair example. Also to instruct the young reader to teach his customers not to spoil their natural springs and wells in the future, for had this been taught by our forefathers of the plumbing trade, London to-day, to a great extent would have been much better off for the precious fluid of life.

I remarked that I have a matter of some years to spare, and prefer to give you a general outline of the waters of Bayswater neighbourhood, but must beg to be excused if I should come rather near to modern times on this subject without first bringing forward the second line of lead pipes from *Bayswater* to supply the City; an account of which I will give after I have finished with Kensington. It would be, perhaps, irksome to my reader if I stopped half-way on the road of my account of the general water supply about the Bayswater and Kensington neighbourhood.

Round about here were many other springs and bournes which ran by the side of the roads, especially those about where now Westbourne Terrace is built. There, also, bournes ran by the side of Craven Road, Elms Lane, now called Elms Mews, where nearly all these springs and bournes, even those from the neighbourhood of Hampstead, met, and it should be remembered that this was a bourne of no small magnitude, the head of which originated from the natural springs of Hampstead and Edgware, and also conveyed down the greater part of the rain water, which, if you consider the size of these two places, will give you a fair idea of the size of the stream in wet weather. These two streams met about 400 yards about Kilburn Bridge, and ran down the boundary line of Willesden parish, which was then known by the name of Bayswater rivulet. It then turned round at the Mead, through what was known as the fourteen acres, under the Canal, then under Harrow Road, and for some little distance was covered over, and out again at Ranleigh Street; then on the east side of Elms Lane, and under the Oxford Road into Hyde Park Ponds, which were afterwards converted into the present form of one long sheet of water.

There is something not generally understood about this neighbourhood of springs, then small rivers for Bayswater, fifty years ago, was to the then great citizens what Brighton, Ramsgate, or Yarmouth is to the citizens of London of the present day. All around Craven Hill now called Craven Street, even as far up as Black Lion Lane, which is now Queen's Road, also Leinster Terrace, and as far down as Cheese's gardens, where now stands Lancaster Gate, were nothing more nor less

recreation grounds, where all kinds of sports were practised—balloon ascents, and such like. These Cheese gardens were a series of tea gardens, similar to those now existing at Kew, and about the vicinity of Hampton Court. I have said that there were all sorts of games practised about this neighbourhood, but must dwell upon this, that there was some excellent trout fishing practised about these parts. Here is a proof of the purity of the water, because you very rarely find good trout in inferior water.

There were also two excellent swimming baths of a tripezoid shape, nearly opposite the point where the Serpentine pumping engine now stands, 100ft. from the Bayswater Road, between Bayswater Place and Union Place, and supplied from the springs just above.

Paddington, Bayswater, and Kensington, as you have seen, have been noted for the purity of their waters, but this is not all, for they have been very much noted for their mineral springs or wells.

There were chalybeate wells; also in this neighbourhood lay, about half-way between Bayswater Road and the Round Pond, a well, having a pump, whose water was exceedingly "irony." There was another well of a mineral character, known as Saint Agnes' Well, which stood just on the east side of the Bayswater pumping station, in a line with the stone seat that is there at the present time, and was about twelve yards on the south of the seat. This well was about 3ft. square in shape, lined with stone, having two steps to go down, and at the back of the well was a stone door, which opened into a kind of stone-built tank, which was the conduit head, from whence the water flowed to the dipping well. This well was so much appreciated about thirty years since, that I have seen as many as twenty neighbouring servants waiting their turn to get a can full of this precious water; and to show how it was sought after, those water collectors could only get it by first obtaining a ticket, which was only to be obtained through the park ranger, or some such individual. There are only a few people left that know anything of this well. However, I, by chance, found George John Wilson, Esq., an old gentleman of the neighbourhood, from whom I have received useful confirmation thereon, and information respecting the neighbourhood generally.

ST. GOVOR'S WELL.

The history of this well can be traced, at least, to the time of Queen Anne, when it was simply a pond half as long as the comparatively new Round Pond is to-day. This is situated a little on the right of the broad walk, between Kensington High Road and Kensington Palace. It is sunk about four or five feet down into the ground, with stone steps to go down to a dry bottom, wherein is a waste trough and drain. Where does this natural drain go to? and is the real spring now running therein at some unknown spot? Remember, there are still scores of acres of land about here undrained artificially, and where does the 30in. per annum of rain water go? There are iron rails round the top part.

When the Round Pond was emptied to make it a uniform depth of about 2ft. 6in. to 3ft deep all over, and as a preventative against drowning in skating seasons, to the great surprise of the know-all inhabitants, who thought this was a natural spring, at one time, found it streamless, and absolutely dry, as it remained after the necessary alterations were completed, the spring having ceased, a percolation from the Round Pond, filtered through sand, resulted. To satisfy the wishes of the juveniles, and others, who constantly visit this part of the gardens, a water company's pipe was laid on to this old, but then exhausted spring, which, instead of flowing, as of old, now has to be obtained by pressure with the thumb. They (the gardens people) also fixed another granite pillar fountain on the apex of the south bank, and near the Round Pond, just before coming to Queen Victoria's statue, which is on the left.

In the same district a well was sunk and bored in all to a depth of 250ft., and when the chalk was touched the water rose with great rapidity to within 70ft. of the top. There appears to be a fault in the chalk strata, as shown at W, Fig. 959A, for when the artesian well which supplied the fountains was bored, they had to go 300ft., yet the distance between the two wells is not more than about 300 yards.

HYDE PARK PONDS.

As before stated, these were supplied partially by the West Bourne; but there was another stream which came from Paddington Green. These two streams joined at Bayswater Road, ran through the ponds, and emptied at Knightsbridge and twirled about until they reached the Thames. These ponds also used to supply the western part of London, until a complaint was made by the king's keeper of deer, who petitioned King Charles I. to discontinue the supply to London, which he did. But, although the supply was discontinued to the western part of the City of London, they managed to supply the Houses of Parliament and Government buildings, and also Westminster Abbey with the best of the park springs, and the *Lancet*, as late as 1848, said: "Drink every morning of these springs," showing, even at that time, the highest medical paper was in favour of them.

THE SERPENTINE.

In the year 1730, Queen Caroline instructed a Mr. Withers to form the several ponds or pools and springs between Bayswater and the bridge, at the south end of the Serpentine, into one continuous sheet. But as the Hampstead Brook began to fall off, through the digging of sewers, &c., and otherwise becoming contaminated, it was deemed prudent to search for other sources, when a well on the west side of the Bayswater Brook was sunk by a Mr Coulson, who went down 300ft. before he found what he considered a sufficient supply.

There also used to be a good drinking spring near the outlet of the Serpentine, where the Druidical or potato-shaped stone now stands, and, by the larking juveniles, known as Stonehenge. But this is done away with, as is also the old conduit that at one time supplied Westminster, and the only thing that is now left is a kind of square marble pillar monument about 2ft. square and 5ft. high, situated about 80 yards north from the middle arch of the bridge and at the extreme bottom end of the Serpentine, near Knightsbridge, with the following inscription thereon:—

> A SUPPLY OF WATER BY CONDUIT FROM THIS SPOT
> WAS GRANTED TO THE ABBEY OF WESTMINSTER,
> WITH THE MANOR OF HYDE, BY THE KING
> EDWARD THE CONFESSOR. THE MANOR WAS RESUMED
> BY THE CROWN IN 1536, BUT THE SPRINGS
> AS A HEAD AND ORIGINAL FOUNTAIN OF WATER
> WERE PRESERVED TO THE ABBEY
> BY THE CHARTER OF QUEEN ELIZABETH IN 1560.

There is also another old landmark of these conduits situated close to the rails and near the end of the last house from Knightsbridge going towards Hyde Park Corner. This curious-looking old stone structure, with door in front, is an old well, within which is the cistern. It was also the place where at one time stood a windmill,

and a little further from there, to the west, was a water-wheel, both used for pumping purposes, and about this spot used to be a sluice door valve or cock from the Serpentine, which, after the new line of pipes was made, was fixed on the east side of the old monument, where the Green Park arch now stands.

The Serpentine to this day supplies a portion of Buckingham Palace Grounds and the Green Park ornamental water, and cleansing water only for the Houses of Parliament, &c. The supply from the Serpentine is nearly opposite the before-mentioned square marble pillar monument, and now takes its course across the Rotten Row to Marble Arch, across Piccadilly Road, and enters the Green Park on the left of the Wellington Statue, or what is now known as Constitution Hill, where there is a reservoir, which receives its water from Orange Street. The Serpentine pipe has a cock just at this spot. This Serpentine pipe is continued towards Buckingham Palace on the east side, and thence to near the south side of St. James's Palace. It then goes somewhat diagonally across the Park, and under the ornamental waters to the island, under the water again and across by the corner of the Foreign Office, up Downing Street, and to the Houses of Parliament, where it rises up through a fire nozzle 30 or 40ft., this point being fully 60ft. below the water in the Serpentine. Branches from this pipe supply a lot of public offices with cleansing water *only*. The Houses of Parliament, the Admiralty, the Treasury, the Duke of Buccleuch's—and even Grove's, the fishmonger's shop right opposite the Admiralty and Buckingham Palace—the gate-keeper's houses, and when required the Serpentine, &c., are all supplied with drinking water from the Trafalgar Square Waterworks, Orange Street Well, which is an artesian well, before spoken of, of 384ft. depth.

There are a great number of private and partly public wells sunk and bored about London for supplying squares, private houses, and flats, where it comes much cheaper and more reliable in quality than that obtained from some of the water companies.

There were also a large number of wells and springs at Kensington Gravel Pits, which were situated at the top end of Church Street, and to about half-way between the Notting Hill and Kensington Roads. There was another fine spring in the Wilderness, that is a place situated between the Bayswater Road and Kensington Palace, or at the now green at the back of Palace Gardens, and in a line with the east side of the Kensington Palace.

KENSINGTON PALACE SPRINGS.

To this day there are several springs of water at Kensington Palace, one being in the framing ground. There is another in the passage at the entrance of the State apartments, housekeeper's residence, one in the basement of the Palace, and several others close at hand. But recently Dr. Jenner thought they should not use the wells for domestic purposes.

About 1730 there was erected a tower on the west end side of the entrance, and almost in a line with the cottages, or perhaps a better description of measurement will be sixteen yards from Palace Gardens Road rails, and sixty yards from the corner of the south boundary wall of No. 15 Palace Gardens, which gives the exact spot. This old tower was called the Water and Bell Tower, of which Fig. 959D is the elevation. The tank was wood, lead lined, and fixed on a line with the first stringing course at A, B, with the overflow at F. G, the Bell Tower, which was used in case of fire only. This water tower was supplied by pumps, the well of which was about 20ft. deep with 12ft. of water, and situated between the first two elms, or about fifteen yards from the Palace Gardens Road and eight yards towards the Palace, on the left going out of Palace Gardens Road, towards and in a line with the entrance gate into Kensington Gardens, where Princess Louise's studio now stands. There was also a well within the building, and a pump fitted up for emergencies.

Fig. 959c is a representation of a well, pump, and cupola, which was erected by Mr. Gunton, a plumber of large practice in High Street, Kensington, about 1630, who put down the original pumps to supply the tank shown above, which tank partially fed the house belonging to—or, at least, that which was formerly used by—King Henry VIII., and was afterwards used by William III., to supply, or partly supply, Kensington Palace, and, as before referred to, the fountains. After this, it was used to supply the Water and Bell Tower. The pumps and machinery there shown are of a later date, by Warner's *old* firm. The Water Tower, Fig. 959D, was built expressly against the ravages of fire on the Palace, and to supply the north side of High Street with water. The height of the said tower being as follows:—

	ft.	in.
Height of the middle tower to the stone fillet ...	26	3
Above the stone fillet to the top	3	8
Height of the middle tower...	29	11
Height of the outside turrets above the middle tower	10	7
Height of the outside turrets	40	6

I may say that I personally fixed up a similar piece of work at Little Sutton House, near Turnham Green, about the year 1862, for Dr. Clayton.

Water Wheels and Windmills.

At one time the Kensington Palace was supplied with water pumped by a water wheel, and after this by a windmill fixed at the Bayswater Brook, near the head of the Serpentine, but when the Chelsea Waterworks started business, on consideration of being allowed to draw their supplies from the Hyde Park pools and springs, they were in return to supply Kensington Palace and to keep the Round Pond full of water. But when the waters of Bayswater fell short, and became somewhat polluted, the Chelsea Waterworks Company was compelled to take their supply from the Thames, and with such water the Kensington Palace was, and is to this day, supplied. The Serpentine water supply in due course fell short, and hence the Serpentine artesian well, which, although sunk and bored into the chalk, gives water of an inferior quality, owing to the quantity of water from the now polluted springs finding way therein between the earth and brickwork, and otherwise.

At this Bayswater pumping station there are two 30 horse-power beam pumping engines. I have had great difficulty in obtaining personal proofs, owing to the officious policemen stationed on duty at the Kensington Palace, who were most insulting, for no purpose whatever, and a sergeant, behind my back, even went out of his way to tell Mr. Jones, the general foreman of works at the Palace, whom I had asked a few questions relative only to this work (who, as usual, knew everything, but proved old women's chat), not to have anything to do with me. This is not the first time that these insipid nondescripts have interfered with the progress of this work, and it would be much more to their credit if they did their duty where it is required.

The before-mentioned pumps work as follows:—One pumps the water from the well direct into the Round Pond and also into a small reservoir from which the other en- pumps by a centrifugal pump to supply the fount- They work ten hours per day, Sundays excepted, which day these fountains are supplied from the wate- the Round Pond. Of course, the waste of these founta- goes to supply the Serpentine.

ACTON WELLS AND SPRINGS.

The well water here is more powerful than any other in the kingdom, except Cheltenham, which is considerably stronger. Here the weight of salts is 60 grains to the pound of water, whilst that of Acton contains 44 grains in the pound. There are also some good springs about Ealing, and especially Hanwell.

THE HAMPSTEAD RESERVOIRS. MERCHANTS' WATER WORKS.

These belonged to the Hampstead Waterworks, and are of considerable ornament to Kenwood. The springs were held by lease under the City of London, and supplied parts of the Tottenham Court Road in 1795.

These works consisted of three engines and pumps for raising the water by windmills, which were situated in the fields near Portland Road. There were two other pumps worked by the common sewer at Tons Coffee House, St. Martin's and Hartborn Lanes, Strand, with three main pipes, 6in. and 7in. bore, therefrom, which supplied the neighbourhood at a rental or tax, which profits they divided half-yearly.

I may here remark that neither the Highgate nor Hampstead Ponds, which yield 99,863 gallons daily, are now used for domestic purposes.

Wooden Pumps.

The last of the wooden pumps in London known to me was fixed in 1576, in a well dug 24ft. deep; its situation was in the parish of St. Andrew, Lime Street Ward, at the corner of Lime Street, but, curiously, this pump only lasted twenty-four years, by reason of its rotting, on account of the well not being properly ventilated. It was taken up, and a leaden one fixed in its place.

The Analysis of Kensington Water.

In the parish books it is recorded that the mineral spring and well house, which stood at the Notting Hill House, so late as the year 1698, were rated at 15s. In the following year they were owned by Dr. Wright and partners. In 1720, Mr. Town had possession, and in 1821, a Mr. Reid was occupier. The wells for many years were of considerable resort, and Dr. Allen, in 1711, analysed the water, and this is how he describes it: "Two quarts had fifty grains of earth in it—light, leafy, and grey—which distilled vinegar wrought (acted) upon, the water boiled up, had many selenitical particles in it. The salt was soft, and ready to shoot into figures; the striæ flat, and mostly not pointed. The salt melted not easy, as Epsom salts, but bore a good heat and had a much greater quantity of earth in it, was hard on the tongue, and did not show a scum till nearly boiled up. This salt did not trouble a solution of fine silver in spirit of nitre, which, in a long time precipitated, and so quick and large, as with sea salt, so it appeared a high alkali, cretaceous and nitrous."

Monro also speaks of a Kensington spring as containing a calcareous Glauber salt, with a portion of sea salt.

Such a spring was also used as a public bath, and was situated nearly opposite the Katherine and Wheel, Kensington. It was a spring greatly sought after.

The London Conduits (*continued*),

Or the Second Conduit, date 1432.

The ground, which has been so much mixed up and confused with the original, of these springs was situate in the parish of Paddington, at Bayswater, and owned by the Abbot of Westminster. He granted Robert Large, for the citizens of London, a head of land, together with all the springs thereon; this land amounted to 26 perches in length and one in breadth, and to prevent it becoming their freehold they were to pay on the feast of St. Peter a yearly rental of two peppercorns.

There were several springs upon this spot of land, one was situated 500ft. due west of the centre of Spring Street and between Westbourne Terrace and Gloucester Terrace. The other, a large one, was situated upon the same land, but 165 yards from the present park rails over the West Bourne and opposite the pumping station at the head of the Serpentine, but 385 yards N.N.E. of the pumping station. These springs and conduit heads have been the means whereby many streets derive their name, to wit, Spring Place, Spring Street, Spring Cottages, Conduit Place, Conduit Mews, London Street, and a host of other names are all close upon the spot, and though there are inhabitants there eighty years of age and upwards, and living there all their lifetime, not one could give me any idea of the exact position of these conduits, although I have been hunting them up for at least the last five years. Some would say, "Oh! it must have been at Spring Place," others would say Conduit Mews, others in Talbot Square, where the old Grand Junction Reservoirs stood, others would say at West Bourne or Tybourne Brook, which produces a fair medley in one's notes. You see the size of this reservoir was 26 perches in length and one in breadth, and to prevent it from becoming freehold the citizens had to pay to the Abbot of Westminster a yearly rental of two peppercorns at the feast of St. Peter. Here they again tried, but in vain, the foreigner to cast the pipes, and Henry VI. authorised the mayor and citizens, by writ of the Privy Seal, to buy 195 tons or 200 fothers of lead for this undertaking which was not half enough. The King also gave orders for the authorities to press plumbers and labourers to make by hand labour the pipes, and to work at the undertaking or laying them in position, and, on their refusal, to transport themselves (which many had not the means to) from the country, or to be imprisoned in the State prison during the whole term of which the work remained unfinished.

Bayswater Conduit Lead Pipes.

These pipes were of 2in., 3in., 4in., 5in., 6in., 7in., and 8in. bore, made from 16lbs. to 32lbs. to the foot super, and in 10ft. lengths, having sand burnt joints 2in. wide, as shown at A in the woodcut, Fig. 959B. S represents the sand, and B B the sand boards for keeping the sand up. The half wood mandril being shown at WOOD for the purpose of using less sand, thus making the pipes lighter, and, by first drawing the half mandril (tapered on the sand side), the sand easier to get out.

You have seen the position of the springs, but there is another thing to be shown, and that is the shape of one of the buildings which was used to protect the mouth of the pipes from being interfered with by malicious or mischievous rascals, who at first used to meddle with the inlet of these pipes, by throwing solid bodies and small animals therein, which used to choke or partly choke it up, also to prevent the wells being stirred up. This building is shown at Fig. 959C, which was of strong built stone work with iron plated door in front. The leaden pipes were down 3ft. below the water level, and the tank itself was curbed with stone curbing open at the bottom. The spring yielded about 30 gallons per minute. The pipe was a 7in. one. Now, taking the fall as 30ft., and the friction of the water through three miles of pipe, you will then be able to see what amount of water could be drawn, assuming that every tap on these pipes to be open, not taking bends into consideration, and two of the springs being connected to form one conduit head by suitable culverts.

CONDUIT TERMINALS.

The conduit in the West Cheap and by St. Paul's Gate, about the year 1442. This was restored, and one thousand marks was granted by the common council for the rebuilding and repairing of the other conduits. This West Cheap fountain or conduit was destroyed by the Fire of London, but it was never properly finished. These conduits became a nuisance from the gathering of parties of serving men and servant girls, who used to parley and scandal the trade folk. They would stick there all day with the professional water-carriers (strong healthy men), who supplied the rich neighbourhood with water, and who were indispensable to the citizens in those days. But this was not all, for the chummies (sweeps) patronised these conduits, and were known to barricade them with their brooms, waiting for hire, and one jocular kind of historian, Ned Ward, in 1700, states, "A countryman, seeing so many black attendants waiting at the stone hovel" (conduit), "took it to be one of Old Nick's tenements."

THE FLEET STREET CONDUIT.

This was supplied from the conduits of Marylebone and the overflow from the Holy Wells of St. Clement's and St. Bridget's, and people did say that St. Bridget's Well was drained at the time of the coronation banquet of George IV. In 1358 the people of Fleet Street, it is said, received more water than they wanted from these conduit pipes, in fact, so much so, that their cellars were often inundated; upon which complaint, and to satisfy them, they were compensated, by a privilege of erecting a small conduit house opposite John Walworth's house and the house of the Bishop of Salisbury, now Salisbury Court. But it seems that some of the inhabitants were not satisfied with this, for it is recorded that in 1478 an inhabitant was detected tapping the conduit pipes for his own use, and for this villainous offence he was embellished with a headgear in the shape of a cone, like the top of Fig. 959c, and, headed by the town-crier, with bell and mace in hand, who cried out how the culprit tried to rob the citizens. He was also followed by a yelling crowd, who, as usual, to give them sport, pelted the offender with rotten eggs during the march through and about the City, which penalty was considered a just punishment, instead, as was the usual thing, of being flogged to death.

THE STANDARD CONDUIT IN FLEET STREET.

This was really at the bottom of Ludgate Hill, and erected by William Eastfield's executors about the year 1478. The same gentleman also built the conduit standard in Aldermanbury, then used to point out measurements from London (as did the stone at Cannon Street). This latter conduit was originally supplied with Tybourne water.

There was another standard conduit erected in the year 1582, at the east end of Cornhill, at its junction with Gracechurch Street. This also seems to have been a measuring post, probably for the easterners, and we are told that Peter Morris, the London Bridge Waterworks engineer, built this said standard, and supplied it from the vicinity of St. Magnus Church.

The conduit or fountain in Grass Street was erected in 1491.

The conduit at Holborn Cross was erected in 1498.

LAMB'S CONDUIT.

The one in Lamb's Conduit Street (whereof the name of Lamb's Conduit Street) was erected by the bounden duty of William Lamb, date 1577. Lamb also built a conduit at Holborn Bridge, it is said, at a cost of £1,500, and gave permission to the poor people, especially women, to carry water therefrom and sell it to the rich. He also gave them 120 pails for this purpose.

The little conduit by the Stock Market was built in 1500, destroyed at the time of the Fire of London, but since rebuilt, and was called the Fair Fountain or Conduit, on account of its richness and beauty.

The conduit at Bishopsgate was built in 1513.

The conduit or fountain against Coleman Street at London Wall was erected in 1528.

The conduit at Aldgate Without was built by the citizens of London, and supplied by the Hackney conduits (of which more anon) in 1535, which proved a nuisance by the water carriers, when it was removed into a side court.

The conduit at Lothbury and in Coleman Street, and near to the church, was built in 1546.

Dowgate conduit was supplied with Thames water, and built in 1568.

ANNUAL CONDUIT INSPECTION.

There were a great number of fountains and public wells besides these, which were a kind of water mark, almost worshipped, in fact, so much so that they used to make an annual excursion around them, headed by the Lord Mayor and his tribe, and worshipful persons, or divers masters and wardens, who used to ride on horseback around these bounds, after which they thought proper to breakfast or lunch, then play with the harriers until they had killed a hare, Paddington then being part of Middlesex forest. They would then have dinner at their banqueting house, which was situated on the north side of Oxford Street, near Stratford Place, where some ancient conduits belonging to the City of London were. These were most beautifully built, and the City officers used to frequently visit these places, which were pulled down in 1737, and the conduits arched over, when they were refound some few years ago by the Grand Junction Water Works people, whose engineer, Alexandra Fraser, Esq., told me on July 26th (the day I wrote this) that to make the place more safe he caused them to be filled up.

HUNTING IN LONDON.

After these officers had dined they would indulge in fox hunting the remainder of the day. I should think a pretty heavy day's work. However, there is no question but what this was practised at the time, and we read in the historic records that Harper, the Lord Mayor, did such a round on September 18th, 1562, when he, after such a day's work, rode through London to his house, then in Lombard Street. As before stated, it was death to anyone spoiling or defacing these fountains.

ATTEMPTS TO STOP WATER RIGHTS.

We have seen now almost enough of these old fountains, or conduit terminals, and the laws relat ng thereto, but let us see what was done with those that dared to confiscate, or stop his neighbour going to and from the Thames for this precious fluid.

The citizens partly supplied themselves with water by fetching it through lanes and walks, which led to the waterside of various wards. But, in time, some of the owners thought they could do as they liked, and went so far as to stop up these walks; and would suffer none to pass nor repass without paying a duty for the right-of-way. The citizens, in the time of Edward III., induced the mayor, aldermen, and commonalty, to see into the matter. An inquisition was made, and several of the wards were sworn to make diligent enquiry into these grievances, of all persons who brought in presements of these annoyances, and the following are the results.

That in the Dowgate Ward, Armenteres Lane, where was once erected a convenient bridge, the supposed adjoining landlord (one John Weston) thought fit to stop, by building a shop, to the annoyance and inconvenience of the surrounding inhabitants.

There were similar occurrences in Wolfslane, Bretasklane in Ebbegate, Windesgoslane, and also in Cosireslane, all of which nuisances were rectified to give the neighbours back their right-of-way.

Ketherslane, Dowesgate. Here they (the supposed owners) had thought fit to build various houses and out-offices, which were filthy, and interfered with the rights of the people in passing: this was rectified.

Hey Wharf right-of-way was re-established, as also were Eltowlane, Dakmerlane, Reygateslane, Sackeslane, Brodelane, and Dorkingslane.

In Vintry Ward, Vintrieslane (where there was a bridge), Spitelsglane, Conventrieslane, and Midelane, were rectified by being re-established.

Then in Queenhith Ward the key (quay), called Queenhith, which was, at one time, a common way to a closet in those days, known as jake. This key, William Fitz Rase de Blithe, wanted, for its use, six marks per annum, and which was righted to the commoners.

A lane in St. Michael's, Queenhith, was stopped: as was the key, called Salt Wharf, and a bridge, called Cauendres Bridge, in Timbrehithe: and Ruse de Riens, oystermonger, was over-reaching by way of taking money of the poor women that washed their clothes in the Thames, or fetched water therefrom by passing his grounds: all of which were rectified.

In Ratonslane, in the aforesaid parish, the abbot of Lesnes made a pale (enclosed certain grounds to prevent access to the river), which was torn down, and their rights rectified or re-established.

Lokkingelane was let for a sum per annum, which renting was an injustice, and injurious to the commonalty; this was knocked on the head.

Another lane between the tenement of Earl Marshall, and Walter Gladvyne, was, by jakes, considered a nuisance to the commonalty, who patronised this walk for the purpose of fetching water, which jakes, the before-mentioned people, or landlords, were compelled to keep wholesome, so as not to be offensive to the pedestrian water-carrier. A lane, called Fish Wharf, where Simon de Twinham took tolls, was done away with.

There were scores of other lanes and right-of-ways to the water-side by landlords interfered with: but this interference was held to be invalid, and the rights of the people happily maintained.

We have seen now quite sufficient of the law and position of the conduits, and the roads leading to the water supply, I will now proceed to examine other sources thereon.

FREE ACCESS TO LANDS FOR WATER.

In Henry VIII.'s time, that is to say, in 1544, the corporation of London was allowed, by Act of Parliament, to obtain good and wholesome water through pipes from villages, or other lands, within a circuit of five miles from the City stone in Cannon Street.

He also gave orders that they may enter anyone's ground not enclosed by walls of stone, brick, or hedge, and to dig pits, trenches and dishes, to erect heads (reservoirs), lay pipes, and make vaults, suspirals, &c. And in the year 1546 a law was passed, by which those who destroyed conduit heads and pipes, were put to death.

HACKNEY CONDUITS.

The history of these is as follows:—By charter of incorporation, dated May 8th, 1610, there was an Act empowering Dr. Sutcliffe, Dean of Exeter, to set on foot a project for building King James' College, of which Prince Henry was a zealous friend. The King endowed it with the reversion of certain lands at Chelsea, laid the first stone, gave timber from Windsor Forest, and by an Act empowered them to convey water from Hackney Fields, between Lock Bridge, for which purpose they were allowed to dig a trench not exceeding 10ft. in breadth, erect engines, or water wheels, open grounds, and to make conduits for supplying the City of London, at a rental to raise a permanent endowment for this college.

PLUMBERS' COMPANY (*April 12th, 1611*).

We have now arrived at the time of the completion of the Plumbers' Company 1611, when they were doing good work. This old company's antecedents seem to have begun pretty early, the ordinances of which date back from Edward III., about 1330; and, according to what I can glean, at the date 1440 from old trade books, our Plumbers' Society being the oldest in England), they had a pretty rough time of it; for, although they were considered an independent body, they were not by far their own masters, as is proved by the fact of them being pressed to work on the plumbing job of the building and making of the second Bayswater or Paddington conduit, which was in full swing about this time. One would think that work would have been pretty plentiful, considering the fuss they made of what they considered to be an injustice, by others dabbling in the trade; for, according to their account of the wording of their ordinance "that no one in the trade of plumbers shall meddle with works touching such trades, except by the assent of the best and most skilled men in the trade, testifying that he knows how well and lawfully to do his work, so that the said trade may not be scandalised, or the commonalty damaged and deceived by folks who do not know their trade." Here was a pretty state of things, and a fair specimen of society rules: Was it jealousy? Although a man was legitimately apprenticed to the trade, and might have been a first-class workman, he must be recognised as one of them, before they would admit him, under the plea that the trade may not be scandalised. I don't like this plea. Here is another bit. "No apprentice be taken who is greatly disfigured in any part of his body, whereby the honour of the City, or the honesty of the craft, shall in any way be emblemished." I wonder if they thought a boy disfigured by having on his back a birthmark. Here is a little bit more. "That all apprentices be kept indoors in all suspicious times and seasons, so that they may not use any unlawful games, occupations, or misrule to the dishonour and rebuke of the good folks of the craft." How about keeping in a London apprentice in those days? Was this possible? or are they fairy tales which are told about the rollicking, ungovernable, shall I say ungodly, London apprentice of those old times, when we are told that no man, woman, or child, was safe against the ravages of these demons?

There is a heap more of such recorded nonsense, but the above is sufficient to show the state of the trade in those days, yet there is row enough with some busybodies because we have rules in our modern Plumbers' Societies, whereby our men simply stick out for their legitimate wage according to the district.

I here record it that, for hundreds of years, this old Plumbers' Company, although a practical society at one time, dwindled down to an entirely non-practical body of gentlemen, of whom I have nothing to complain, except the misrepresentation of title, and who, instead of being a recognised trade union of thoroughly practical plumbers only, were looked upon more as a society of merchants, who had no pretentions to the plumbing trade. Just before George Shaw, Esq., C.C., and practical plumber, took the mastership in hand (date about 1884), I asked the plumbers of England to form a meeting or congress at the Health Exhibition, South Kensington, to inquire into the status of the trade, which the Plumbers' Company, but only through the intercession of their master, George Shaw, joined in.

I would here remark that no one should have a right to be admitted into such a company of plumbers nor other mechanical, chemical, or art societies, and to swag as a full-bloomed member, unless he has a thorough knowledge of the working of such trade or profession; and I for one would enforce the rule that no one should *meddle* or be in anyway mixed up in a trade or society simply as a figure head. This, it should be remembered, refers to all trade societies—worshipful or otherwise. Nor should anyone be allowed to trade in or under a false title, especially such as sanitary engineers, 99 per cent. of whom to-day are trading under this deceitful title; and more than 50 per cent. of these people in London are falsely representing themselves on signboards as practical plumbers, who know nothing about the trade, but are thoroughly outsiders, more than half of whom were not brought up in the building trade. Yet these people scores and scores have applied for registration, which if they cannot get from the Committee of the Registration Scheme, get worthless certificates from quack sanitarians or pirate societies, of which I am sorry to record there are more than one in London.

Every word which I spoke to the thousands of plumbers in the International Health Exhibition, held at South Kensington, London, in the year 1884, should be drummed into the ears of the apprentice plumber, as follows (this is a sworn copy of the verbatim shorthand notes):—"So far as our sanitary plumbing is concerned, health and life are in a measure dependent upon the establishment of a Metropolitan Board of Examiners of plumbers' work. What do we find? We find blacksmiths, ironmongers, carpenters, bricklayers, linendrapers, undertakers, painters, glaziers, coppersmiths, tinkers, aye, and even the travelling scissors-grinders, setting themselves down as plumbers, to say nothing of the fold of builders' clerks which come in to swell out the lot.

"This being so, you need not be surprised that the public are so embittered against us, and who put the real plumber in a false position. They, the public, don't know that they are being gulled by a pack of outsiders professing to be able to undertake sanitary work; and, moreover, can you wonder that the public have held themselves so much aloof from even those who are capable of doing good work. In short, I say that the public have, through the abominable way in which their plumbers' work has been scamped, just grounds of complaint, and unless we prove ourselves in this our cause of to-day to be in real earnest to establish examiners as to who are fit and qualified workmen, and to appoint real plumbers for examiners, we cannot expect to re-establish a healthy position for the qualified plumber. This being so, now or never is the time that we should bestir ourselves to alter from bad to good plumbers' work, and to establish in every district a qualified examiner with power to inspect all plumbers' work, and so condemn the works of the tinkering outsiders. In the first place, I would suggest that a board of thoroughly qualified *practical*, and here I speak loud, practical—yes, practical and theoretical plumbers as examiners, which should be established at the Worshipful Company of Plumbers: but which board should be called the Metropolitan Board of Plumbers.

"Their duty should be to examine candidates wishing to become registered plumbers.

"The method of examination should be by practical and theoretical demonstrations. Let the candidate—be who ever he may—he should have such work to do as would prove whether he be a plumber or not.

"For argument's sake he should be able to work sheet-lead, such as is generally found about roofs. He should be able to work pipes in a good practical manner; be a good joint maker and know how to make his own solder; make rough drawings, and have a good knowledge of the necessary water works' fittings of the best and *well tried* class.

"He should be able to answer questions relative to sanitation, but not to swag as a sanitary engineer, but to kick all the before-mentioned blacklegs found arrogating to themselves this title.

"He should be able to answer questions relative to why he is executing his work in the way he is doing it, and to make drawings of it when done, say of a sanitary job complete. He should also be tested as to making arrangements; to wit, let him show and arrange a tier of closets with proper ventilation, and a system of house and stable drainage. How he would arrange his cisterns, baths, lavatories, and lavatory waste, and such like, with suitable materials. He should also be able to show by plan and elevation, and lay down a line of drainage showing proper jointing, disconnection, and ventilation, and when he has passed in these subjects give him a certificate and register him as a qualified workman, who should be eligible for holding the position of a qualified inspector of plumbers' work.

"Next comes the establishing of district examiners. In the first place I would like to give you my views respecting their work, which should be as follows. Their position should be directly under the district surveyor or engineer connected with the parish, but in no way should the surveyor dictate to the plumber inspector about his work, but whenever a point of difference between the two, if a duty trade point, it should be settled by the Metropolitan Board of Plumbers. The sanitary plumber inspector's work should be to examine plans and specifications of sanitary plumbing generally, which should be lodged by the architect with the other plans of new buildings or otherwise; he should report the correctness or otherwise of such plans to the surveyor, and if such plans are made in strict accordance to set rules of sanitary and water-works' plumbing to be hereafter discussed (see Vol. I.). The work should be allowed to proceed, and the plumbing examiner should be engaged under the said surveyor to visit and inspect the work whilst progressing, and if such works are not being carried out in strict accordance to the plans and specifications lodged, then the plumbing examiner's duty will be to report such discrepancy to the surveyor, whose duty will be to insist upon the work being executed in strict accordance with the lodged plans and specifications. In case of alterations in the sanitary or water arrangements of any dwelling house, factory, warehouse, or other buildings, plans and specifications of such alterations should be lodged for approval, and when approved of should come under the same restrictions as those of a new building. In case of any complaint caused by defective plumbing, the plumbing examiner should have power to enter such premises, and condemn such works as are found to be faulty, and to make such plans and specifications as are necessary. The plumbing examiner may be engaged at a weekly salary, and all sanitary inspectors should be practical and certificated plumbers. For I have had my eye upon these men now in office for some years past.

"I now unhesitatingly say that these men are in the wrong place, being mis-named, and, as a rule, totally unqualified for the very important position which they falsely hold. I really speak from my own knowledge, and as this large building is open to all—and especially to all interested in sanitary science, engineers, surveyors, and architects, of which I see many before me—I herewith challenge any one to contradict, and, if so, let him speak out immediately he hears any word which he can disprove. Now, I'm going to hit hard, and I speak of my own knowledge, that by far the greater portion of them are men put into their position simply through the interest which someone has in connection with our vestries, &c. What are the greater part of these so-called sanitary inspectors? Simply old soldiers, men worked into position by the recommend of some old soldier, such as a colonel or general or

officer who has influence in the district. To prove this, look at those of our parish, Kensington, where they have more than one or two old soldiers, and, again, look at Hammersmith, where there is even a retired pensioned policeman and also a retired detective. (Shame, and applause.) Ah, but this is not the worst of it, these men, we have given them a good pension, yet they come on to the parish taking big wages, and after a little while they are again pensioned off. (Shame, shame, and applause.) I will tell you something respecting sanitary inspectorship as practised not a hundred miles from this building. A house was fitted with thoroughly good 10lb. drawn leaden soil pipes, going down the inside of the house, which were in a capital condition, but never properly made good to the drain, as it should have been, with Portland cement; the consequence was that a stink arose and infested the whole of the house. The sanitary inspector was sent for, who, in his turn, recommended a well-known ironmonger to the house owner to come and set matters right. The sanitary inspector made out an elaborate report as follows: Take down present lead soil pipe and fix a 4in. cast-iron one outside, with the usual long paraphernalia of disconnecting wastes, &c. A price was given in to do the work, which amounted to £75, but the house owner could not quite understand this, as the house was built by one of the best and largest firms in London, and no money was spared thereon, so he sought more light on the matter before proceeding. I was, therefore, called upon the scene to make an examination and to give a price in, which I did. The price for putting everything right was 7 6, as the soil pipe was as good as the day it was erected, and only required a little cement to make the connection between the foot of the soil pipe and the drain. Yet the whole of this capital plumbing was condemned simply through the work of the bricklayer. Mr. Chairman and Gentlemen, this is not the first, second, or third time which I have checked these so-called sanitary inspectors from pulling down good work for the sake of [illegible] whims and fancies; and when the public are [illegible] given to understand what is best for their own [illegible], and that they, for the same pay or thereabouts, can have thoroughly practical men to examine the sanitary [illegible] of their houses, there will not be the slightest [illegible] for us to establish a Metropolitan and Provincial [illegible] of Examiners of plumbers' work in every vestry [illegible] sanitary inspector is now established. [illegible] my ideas are condensed to the following: Firstly, [illegible] a Metropolitan Board of Practical Plumbers, [illegible] should be at the Worshipful Company [illegible] offices, at the Guildhall, London. Secondly, [illegible] to practically examine plumbers, [illegible] and practical plumbing, and to give, to [illegible] a certificate and registration, [illegible] qualify him to hold office as a [illegible] sanitary plumbing work; but if he [illegible] not be allowed to practise nor in [illegible] either directly or indirectly, engage, [illegible] in contracting or carrying [illegible] himself as to who is [illegible] to do such work. [illegible] to hold such a [illegible] under Parliamentary [illegible] Thirdly, that, if [illegible] in provincial [illegible] Liverpool, Edin- [illegible] the purpose of [illegible] the laws and [illegible] Board of [illegible] shall [illegible]

The [illegible] incorp[illegible] Act [illegible] on foot [illegible] of whic[illegible] King [illegible] Chelsea. [illegible] Forest, a[illegible]

work. Such boards (firstly) should be affiliated with an established Metropolitan board; (secondly) it should consist of trained plumbers."

This was seconded, and the chairman put it to the vote, which was carried unanimously. And I am pleased to say that the thing is now establishing itself. The board of examiners being at work ever since.

First Public Machine Pumps.

In the year 1582 the first public machine pumps were used in London. They were erected on the River Thames, near old London Bridge, by a German engineer named Peter Maurice. These pumps were of the force pump class, seven inches in bore, having a thirty-inch stroke, worked by an undershot wheel, which was turned by the tidal current and afterwards placed under one, and later on, two of the arches of the old Bridge. The water was raised 120ft. I should say that about two years before the above work was commenced, another engineer, whose name was Russel, proposed to bring water to London from Isleworth—viz., the River Uxbridge—to the North of London.

In 1594 Bevis Bulmer, an English gentleman, undertook to supply a small district of the City with Thames water, to be raised by four large pumps worked by horses.

Other pumps were worked by horses.

Newcome's steam engine was, in the year 1767, erected near London Bridge. This was partially as a security against fire when the waterwheels did not work, and during the turn of the tide.

SHADWELL WATERWORKS.

These works were started by Thomas Neale in 1669, and raised water by horse-power. About 1750 a steam engine was introduced, and replaced by a new one by Bolton and Watts in the year 1774, which pumped at the rate of 903 gallons per minute, or 730,520 gallons per day of fourteen hours—the time worked.

SHADWELL SPA WATERS.

Walter Berry sank this well, in the Sun Fields, which is said to be "impregnated with sulphur, vitriol, steel and antimony." The water was also used to obtain calico printers' salts, to fix their colours. Also it was used for medicinal purposes.

Water Companies and the Public.

A water company was incorporated in the year 1691 to supply York Buildings with Thames water.

Water companies seem to have been going on pretty prosperously ever since. They have obtained Acts of Parliament which are not satisfactory—in fact, the public and many of these companies are nearly always at loggerheads, and not without just grounds on the part of the former. To begin with, the companies' charges are, by some people, considered monstrously high, considering what this necessity of life costs to deliver. The money, so some say, is with most of these companies lavishly squandered by erecting machinery, which often is of a mere experimental character. It is also publicly alleged that some companies give thousands upon thousands of pounds for pumping machinery, which, on the spur of the moment, they consider important improvements, but which, these people say, more often than not turns out to be a complete white elephant. But how about the East London Water Company being opposed when money was required to extend their works to meet the public demand a year or so ago? I would spend a lot more money, and do away with th[illegible] [illegible] ins abounded with fire plugs, the latter of [illegible] water—viz., lumps of wood driven into

a socket, to say nothing about the wretched depth of a large quantity of these pipes, which are only a foot or eighteen inches below ground, and freeze and become clogged with ice from eight to fourteen weeks at a stretch, as was the case this winter, 1895, when the consumers' water was cut off for this period, and who had to get their daily supply by often going from a quarter to half a mile out of their way. Besides all this, the water companies are supposed to give a constant supply by an Act which they obtained in the year 1871, yet here in 1895 it is not near completed, except by the Grand Junction Company.

I may here state that there appears to be a general nasty feeling between the—especially aristocratic—public and the water companies generally, which is brought about by the former not understanding the latter's rules. They have an idea that the water companies are compelled to supply them with water under any conditions, providing they pay the water rate, and the following will give you a fair idea of the ignorance of the public in this matter; but you will see the water companies have held their own throughout the piece, although much tantalized by a pack of half-taught and half-read stupid cuffs-and-collars, or petty police-court lawyers, who do more harm than good for their clients, and I must say that many of the police-court magistrates are as bad for allowing public time to be wasted in such ridiculous suits:—

"At the Newington Vestry Hall, Major-General De Courcy Scott held an inquiry, on behalf of the Local Government Board, into complaints made by residents in Southwark, &c., against the Lambeth Water Company in connection with the supply of water during the late frost.

"Mr. Morton Smith, barrister, appeared for the memorialists and the Newington Vestry, and Mr. H. Wilkins, secretary of the Lambeth Water Company, appeared for the Company.

"The memorial, asking for the inquiry, was sent from the National Model Dwellings Company at Southwark, whose dwellings are said to be inhabited by 2,000 persons.

"Mr. Wilkins claimed that the memorial was invalid, as the signatories did not pay water rates as required by the 9th section of the Act, there being a special contract between the Lambeth Company and the National Model Dwellings Company.

"The Inspector: I shall take a note of your objection, but propose to take any evidence there may be in support of the memorial.

"Edward Pearce Lohmann, of 4, Scovell Road, Southwark, a foreman in the employ of the National Model Dwellings Company, then stated that the water supply to the dwellings failed from January to the middle of April, and the tenants were actually without water from the middle of January to the middle of February. The Lambeth Company did not send water round by carts, neither did they erect standpipes.

"Henry Bowman, another memorialist, also gave details about the defective supply during the frost, and said that the residents were without water for about 15 weeks.

"Mr. G. Hiscocks, the surveyor to the parish of St. George-the-Martyr, Southwark, said that there were numerous complaints received during the frost as to the defective supply. He had complained of the insufficient supply of stand pipes in his district, and the Lambeth Company increased the number.

"In answer to Mr. Wilkins, witness said he only knew of one case of a main bursting—in the Townsend Road—which was laid at a depth of 2ft. 9in. below the surface.

"Dr. Frederick Waldo, medical officer of health to the St. George-the-Martyr Vestry, stated that the Model Dwellings were rendered in an insanitary condition by the insufficient supply of water for flushing purposes.

"A memorial from Falmouth Chambers, New Kent Road, was then dealt with. In their complaint the memorialists said they were all too weak from influenza to carry heavy pails of water from the standpipes during the frost, and they had therefore to pay for it being carried to them. Two of the signatories said the residents were without water for nine weeks.

"Mr. Wilkins, on behalf of the Lambeth Company, contended the memorial was informal, as the signatories did not pay water rates.

"Mr. John Pickering, manager of the Palatinate Dwellings, New Kent Road, said they had 36 blocks of buildings with 600 tenants. During the frost there were many complaints as to the water supply, and several tenants left in consequence of the defective supply.

"The inquiry was then brought to a close, General Scott intimating that he might find it necessary to re-open it at some future date.

"The Inspector also held an inquiry into complaints made against the Southwark and Vauxhall Water Company, which terminated."

"At the West London Police Court, on the 31st May, an application was made by a solicitor" [who evidently did not read the rules properly] "on behalf of the occupier of a house in High Street, Acton, for a summons against the Grand Junction Water Works Company, for failing to supply water. He stated that his client's family, consisting of nine persons, had been without a supply since the 28th of February. The family had been depending on the kindness of the neighbours for water. He produced a receipt for the water rate up to Lady-day quarter.

"Mr. Rose inquired the reason, and was informed by the occupier that he knew of none except the want of connection. The occupier also stated that there was a burst of the pipes, but there was not any frost in them at the present time. He was most anxious for a supply, as his family could not live without water.

"Mr. Rose granted a summons."

[Here the tenant was at fault. He should have repaired his pipes.]

"On the following day at the same court, a question of some importance was raised before Mr. Lane, Q.C., as to the power of the Grand Junction Water Works Company to charge for water which was not supplied through a meter not working owing to the late frost." [The meter being the property of the Water Works Company, whose duty it was to keep it in order. But here the frost clause comes in. And was the meter or the pipes thereto or therefrom out of order? I should certainly say the latter, and much the latter.] "A gentleman in business applied to the magistrate for his advice. He stated that the supply was by meter (which was not working), but the Company had applied for the full amount.

"Mr. Lane said he was afraid it was no answer, as the Company were entitled to charge in advance. It would be another question if the pipes were laid in such a way as to be easily frozen. The applicant, in explanation, said the meter was outside, and not under his control.

"Mr. Lane inquired how the applicant obtained water.

"The applicant said his man went to a standpipe, but for some time he was without water altogether. He applied twice to the Company, and received a formal notice that the complaint would be attended to, but nothing was done.

"Mr. Lane said it was a new question, and the applicant might try it. In granting the summons he suggested to the applicant to call a witness who would be able to show that the defect in the meter could be remedied by the Company."

"On Monday, among the several applicants who waited upon Mr. Lane, Q.C., was a householder, who complained of the action of the Water Company cutting off the supply that morning. He stated that he did not receive any notice until the supply was cut off. He was now without water.

He expressed surprise at the proceeding. He also explained to the magistrate that there had been a leakage in the gutter for some time. The turncock was well acquainted with it.

"In answer to Mr. Lane, the applicant said he had not paid the rate for the current quarter. Mr. Lane remarked that unless the applicant paid the money he could not get water. Before he could have water he must pay or tender the rate.

"The applicant said he was not aware he was responsible for a leakage in the pipes outside the house.

"Mr. Lane, after looking at the sections in the Act, said, according to the applicant's statement the Company had behaved in a tyrannical manner, but unfortunately he was in a fix. He was not entitled to a supply of water until he had tendered the rate. Unfortunately under another section, if there was a leakage, the applicant would have to set it right."

[This came to nothing. Also see Water Companies, the Public and the London County Council.]

I will not insult you by asking what you would think the outcome of all this twaddle was: suffice it to say that the water companies can stand a lot more of such quibbling nonsense. But how about the poor people who are the real sufferers in the case? If landlords will take upon themselves the onus of keeping these people's fittings in such a flimsy condition, and running to pettifogging lawyers instead of going to a good, sound, commonsense practical plumber for advice (and I claim that there are such, although some people say nasty words about us, such as, If you have a son, who is a little queer in the roof, put him to either the Church to become a parson, or to the plumbing trade to rank as a plumber !), I say it serves him right if he loses every tenant. [Also see Hackney Royal Commission on Water Supply.]

Having read the foregoing ideas of the water companies and public, I will now recite Clause 53, Chap. 17, of the Waterworks' Act for April 23rd, 1847. Also see Vol. I. of this work for the Waterworks Act.

Owners or Occupiers entitled to demand a Supply of Water for domestic purposes.

"LIII. Every owner and occupier of any dwelling house or part of dwelling house within the limits of this special act shall, when he has laid such communication pipes as aforesaid, and paid or tendered the water rate in respect thereof, according to the provisions of this and the special Act, be entitled to demand and receive from the undertakers a sufficient supply of water for his domestic purposes."

Notice the words "laid such pipes and complied with this Act."

Also see Clause 72, where it provides for the tenants to pay the water rate to the house owner, who is responsible to the water company.

Here in these two clauses of the Waterworks Act it is actually provided that the occupier is entitled to his supply of water and for the landlord to pay the rate.

What are the Water Companies afraid of?

Sir William Henry Wyatt presided, on May 21st, 1895, over the half-yearly general assembly of the proprietors of the West Middlesex Waterworks. There was a good attendance, and a dividend of 10 per cent. was declared.

He said, with regard to the London County Council, that they had introduced eight Bills for the transfer of the undertakings of the metropolitan water companies, and that they had brought in a separate Bill for each company. The cost of that proceeding was, he said, enormous. When it would come to an end he did not know, but in the meantime it was quite certain that through the action of the County Council they were annually mulcted in a large amount of costs. It was a most objectionable proceeding. They had to pay the parishes about £25,000 a year in rates, so they would see that it was not all profit they got out of water. Their excellent deputy chairman (Mr. Boulnois, M.P.) did all he could to protect their interests in Parliament, and to prevent mischief being done them, and he (the chairman) hoped that they might get out of it better than they thought for. The motion was seconded by Mr. E. Boulnois, M.P., the deputy chairman, and agreed to unanimously without discussion. The dividend having been declared the meeting was made special, when, on the motion of the chairman, seconded by Mr. Boulnois, a resolution authorising the directors to raise £440,000 debenture stock for the purposes of the proposed new works, in such portions as they think fit, was approved.

He said that they had lately fixed two new engines and boilers at Willesden. They were nearing completion, and he hoped they would soon be in working order. The 21in. main from Shepherd's Bush Green to Harrow Road—a great work executed at heavy cost—had been laid and brought into use. The overhead system of unloading coal at the works at Hammersmith had also been completed, and had fully effected the anticipated saving in working expenses. They had also entered into contracts with Messrs. John Aird & Sons for the construction of four storage reservoirs, of a total capacity of 350 million gallons, on the land recently acquired at Barnes, and good progress had already been made with the work, and for laying in various parts of the district several service mains, rendered necessary by the increasing number of houses and by the extension of the system of constant supply, and it was hoped these mains would be completed and available for the requirements of the approaching summer supply. A contract had also been made for the erection of a triple expansion Worthington engine at Hampton, to replace the last remaining Bull engine, and, among other advantages, an economy in fuel would be one of the results of this change. In order to carry out these new works additional capital would be required. The number of new supplies laid on during the half-year was 333, making a total of 78,740. This increase was less than usual, owing to the exceptionally severe and long-continued frost during the early months of the year, and this had also prevented the usual progress being made with the extension of the constant upply, only 2,265 additional houses having been changed from the intermittent system.

Water Companies, the Public and the London County Council, together with the Press.

Copy from the *Kensington News* :—

"There is no question but what there is a just irritation felt at present against the companies on account of their failure to provide water—a failure which is the subject of a Local Government Board enquiry, the first sitting of which was held at Wandsworth on the Tuesday" (the 9th day of April, 1895—this is mine) "on which the discussion at the Council took place. On the result of that enquiry the price that ought in reason to be paid for the works of the several water companies will to a very large extent depend." (Some people say £30,000,000, whilst others say the cost will be £50,000,000. This is mine.) "The Wandsworth consumers were heard on Tuesday. They had deplorable tales to relate. One of them, who paid £15 in water rate and had a family household of nineteen persons, was wholly or partly without water for six weeks, was told firs[illegible]s in his house were frozen, then that the in[illegible] were frozen, then that the com-

munication pipe from the main was frozen; and after great trouble and expense to the consumer in investigating the truth of these random assertions, found the communication pipe frozen on the company's side of the stop-cock connected with his house. The main was clear, but no stand-pipe was put up. Another was waterless for seven weeks, and the main was less than a foot and a half below the surface. Another had no water for five weeks, and the company's pipes had burst in several places. It is only fair to add that the water company has still to be heard, and that these and other witnesses have not yet been cross-examined. On the other side it is to be observed that a contention has been raised that the companies are responsible not only for the mains, but also (contrary to the general impression) for the communication pipes laid by or on behalf of the owners; because" (there it is laid down in the Act of 1871, that the companies have to see, and they should, that every pipe laid for the conveyance of or in connection with water supplied by the company shall, when laid in open ground, be laid at least 2ft. 6in. below the surface, and shall in every exposed situation be protected against the effect of frost. See No. 10, page 271, Vol. I.) "section 24 of the water companies' regulations, passed in 1872, lays it down that they are binding upon all parties, and the companies are the principal parties concerned. Whether this construction of the regulations is legally accurate we are unable to say. The question could be decided only by a Court of Law. If the companies are jointly responsible with the owners and those who act under them for the communication pipes being laid 2½ft. below the surface in open ground and being properly protected against frost in exposed situations, the owners would, indeed, have no right of action against the companies. But the latter could not expect to receive the same sum for mains which were, through their own fault, improperly connected with the domestic service pipes, as they would receive for mains the connections of which had been properly looked after. The case of the mains themselves is of a much more serious character. Where they have been improperly laid at too small a depth, they will have to be laid over again, and this ought to be insisted on whether the companies are or are not bought out by the Council. Any general order compelling the re-laying of the mains would throw on their possessors, whoever they might be, an enormous expense, and would also raise questions with vestries which had altered the level of the roads so as to bring the underlying water mains nearer the surface than the prescribed 2ft. 6in. As our contemporary *London* remarks, the principal assets which the companies have to sell to the County Council consists of the network of mains and pipes spread throughout London. The result of the present investigations may therefore materially affect the price which will be paid for the undertakings. The other assets are the works by which the water is collected, filtered, and brought to the metropolis. In taking these over, however, the obligation of providing a proper supply for the increasing area and population of London would also be assumed; and this, of course, raises the question what is the value of these works, not considered as mere constructions, but regarded as burdened with the above obligation, which may, and almost certainly will, involve the expenditure of large additional sums to tap and utilise additional sources of supply. Shareholders give votes at their annual or biennial meetings. They are consequently responsible for the acts of the directors whom they support in power; unless, indeed, the directors are guilty of fraud. Where they have acquiesced in mains being illegally laid, or have absorbed their capital in large dividends where it ought to have been used in obtaining additional supplies, they may find little more awarded to them than what they may consider to be a merely nominal amount."

How to Deal with the London Water Question.

If I were asked (which is not likely) the best thing to do with regard to the supply of water for London, I should certainly say, take the bull by its horns, and value the whole water companies' good workable plant, leaving out the old and next to useless material, whether it be engines, boilers, reservoirs, filter beds, pipes, valves or other stock. Then, after a fair valuation, and in good faith to the companies for their legitimate rights, which, should they refuse to accept, set to work (whilst work is so very scarce and men starving for want of it), and bring quite an independent and constant supply of pure water for dietetic purposes, and also whilst running the mains, and to save two ground openings, a supply of sea-water for road watering and baths, with properly constructed main pipes marked to distinguish one from the other and running side by side; which I am certain could be done at less cost for *say* one hundred years to come than shilly-shallying about. I spoke of bringing a sea-water supply to London for road waterings, baths, &c., and would urge that this be done, for there is no doubt the water-carts in some parts of London use a vast amount of water—more than is even dreamt of, even by the waterworks companies' people themselves, for what with the wood pavement washing and positively road swilling during the night, and the enormous amount of waste attended, which runs down the sewers, is considerably more in this part of the parish of Kensington than the supply to all the houses put together in the neighbourhood, the wood pavement being actually swilled down nightly. I should recommend the water companies to all amalgamate in the undertaking, and the job could be done in no time, as you have only got to go down to about the Nore for the supply.

LONDON WATER SUPPLY OF 1895.

The enormous supply of water required for this gigantic town is beyond conception; in fact, if the supplies of all the sources were brought together after filtration it would form a magnificent river.

You have seen how the quibbling has been going on with the public, the press, and the water companies, but up to the present it has been an *ex parte* affair, for the water companies will not show their hands until the time when trumps are wanted, and I for my part, as a totally disinterested person, commend them for so doing, especially after the East London being refused the grant of money which was some little time ago asked for and required to extend their storage beds. I shall now place before my readers tables, &c., showing what the water companies of London are doing, together with tables showing the purity of their water, both from a chemical and bacteriological point of view, and leave the matter entirely in the hands of my readers, as I, in writing this work, should not express too strong a view on either side, because there will be no chance to reply, should I hit either side more than they may like. Also see London Water Supply from Wales, East London and Hackney Water Inquiry, &c.

We will now see something about what this water question means to London, and as the East London is now unquestionably the greatest provider, we will take that first in order.

LONDON WATER COMPANIES' DAILY SUPPLY TABLE.

Year.	Daily average Supply in gallons.	Average Population supplied.	Average number of Houses supplied.	Average Supply in galls. per head.	Domestic supply only. Average Supply Daily per House.	Domestic supply only. Average No. of Persons supplied per House.	Average Daily Supply. for Domestic and other Purposes. Month.	Per Head.	Month.	Per Head.	Houses with Constant Supply.
	East London. Filters, 33¾ Acres. Reservoir Storage 615,000,000 galls., for 15·1 days.										
1881	34,543,618	899,671	128,722	38·39							
1885	33,992,521	1,025,034	149,815	33·16	Galls.	Galls.		Galls.		Galls.	
1889	38,102,747	1.105,440	165,139	34·47							
1893	40,856,228	1,165,345	176,034	35·06	185	6·62	January	41·33	October	31·97	175,106
	New River. Filters, 16½ Acres Reservoir Storage 168,100,000 galls., only for 4·8 days.										
1881	28,916,509	1,008,392	133,997	28·67							
1885	28,732,692	1,071,871	144,613	26·80							
1889	31,055,627	1,113,911	152,507	27·88							
1893	37,345,800	1,135,950	156,683	32·88	190	7·25	June	37·57	Dec.	28·28	91,977
	Southwark and Vauxhall. Filters, 26½ Acres. Reservoir Storage 46,000,000 galls., for 1·7 days										
1881	21,634,142	658,654	94,274	32·84							
1885	21,000,616	717,285	104,378	29·28							
1889	21,940,486	751,852	111,155	29·18							
1893	28,371,130	775,467	115,569	36·58	196	6·71	August	40·13	Feb.	33·25	99,443
	Lambeth. Filters, 12 Acres. Reservoir Storage 128,000,000 galls., for 6·4 days.										
1881	17,645,470	450,525	97,603	39·16							
1885	16,739.174	523,852	80,692	41·95							
1889	17,200,187	564,739	89,301	30·45							
1893	21,213,016	604,150	96,819	35·11	175	6·24	June	39·71	Nov.	31·96	59,887
	Grand Junction. Filters, 17¾ Acres. Reservoir Storage 64,500,000 galls. for 3·5 days.										
1881	12,924,541	312,415	44,499	42·74							
1885	15,225,165	343,314	51,456	44·35							
1889	17,019,759	363,218	55,504	46·85							
1893	18,771,164	380,363	58,698	49·35	256	6·48	July	53·43	March	45·99	58,771
	West Middlesex. Filters, 15 Acres. Reservoir Storage 117,500,000 galls., for 6·7 days.										
1881	11,528,835	449,447	57,589	25·65							
1885	41,067,552	507,127	66,378	27·74							
1889	15,318,588	537,385	71,843	28·44							
1893	18,716,776	567,535	76,964	32·98	195	7·40	June	35·82	Feb.	30·60	43,628
	Kent. Pumps direct from Wells into Mains only.										
1881	8,224,860	327,988	53,272	25·07							
1885	10,131,539	392,202	64,401	25·83							
1889	11,119,021	436,041	72,312	25·50							
1893	14,393,701	474,957	79,151	30·30	145	6·00	June	33·57	Dec.	27·59	55,838
	Chelsea. Filters, 6¾ Acres. Reservoir Storage 140,000,000 galls., for 14·7 days.										
1881	8,403,062	234,527	30,801	35·83							
1885	9,258,784	252,118	33,571	36·72							
1889	8,723,841	259,550	35,027	39·61							
1893	10,365,564	269,883	36,669	38·40	226	7·36	June	42·74	Feb.	35·99	18,757
	Totals, showing the increases from 1881 to 1893.										
1881	143,821,037	4,331,619	610,759	33·20							
··85	149,148,043	4,832,803	695,304	86·30	General	Average.					
	160,480,256	5,132,136	752,788	31·27							
	191,033,379	5,373,650	796,317	36·36	191	6·75					

Different sources of water supply to London for the year ending 1893:—

	Gallons.	Proportion per cent.
Thames	37,765,387,678	54·45
Lea	19,115,499,148	27·56
Springs and Wells ...	12,444,846,731*	17·94
Ponds	63,450,189*	·05
	69,362,183,746	

* Non-domestic.

The population of London, approximately, which the eight water companies are compelled to supply, 1893:—

East London	1,174,447
New River	1,141,000
Southwark and Vauxhall	778,910
Lambeth	610,808
West Middlesex...	571,257
Kent	480,360
Grand Junction...	380,836
Chelsea	270,973

APPROXIMATE WATER SUPPLY, &c., TO FOUR LARGE TOWNS.

	Rome.	London.	Paris.	New York.
Daily Supply, Galls. ..	200,000,000	190,033,379	1,000,000	190,000,000
Inhabitants...	670 galls. each head per day.	5,373,650	2,400,000	2,000,000
Houses		600,000	90,000	115,500
Policemen		14,000	8,000	3,800
Firemen		1,000	1,500	1,100
Area in Acres		75,000	18,000	24,000

Approximate water supply to smaller towns per each person: Marseilles, 50 galls.; Chicago, Sydney, and Buffalo, 120; Hamburg, 12.

Drinking Water.

To those who are not satisfied with the water we get for London at the present time, let them go to Wales or to the Lake district, say Windermere, or other such places for a good supply of drinking water. This would be something like a supply likely to last, and could soon be done, now work is slack.

The water delivered by the eight principal companies in London is appalling to the uninitiated; in fact, the amount is beyond conception, the total daily supply being 190,033,379 gallons, for the daily consumption of 5,373,650 or about 35·36 gallons per head, and 238 gallons per house, all of which water is derived from the Thames, the Lea, the Lea Valley, the chalk formation wells, and the Chadwell Springs, not counting the Ponds at Hampstead and Highgate, which, roughly speaking, would amount to 240,622 gallons more for the twenty-four hours; so that you may form some casual idea of the yearly amount pumped by, I won't say the first, second, nor third, but will take the fourth company's returns for it, the Lambeth, whose returns may be arrived at.

According to my table for 1893, which is quite an inconceivable number, I will put it into a kind of river 10ft. wide and 3ft. deep. Here we get a canal of drinking water 8,080 miles long, another almost incredible length.

The New River takes a large quantity from the Chadwell Springs. They have also from twelve to fifteen artesian wells of various sizes, varying from about 12in. to 24in. bore, all on the north side of London. The East London Company has four wells. The Kent about a dozen. The Southwark and Vauxhall, the West Middlesex and Grand Junction draw their water from the Thames at Hampton, whilst the Lambeth and Chelsea draw at West Molesey, and the East London from Sunbury and the River Lea.

The Thames has an area of about 3,500 square miles of water-bearing strata, where rain water can fall upon the earth to assist in supplying the Thames above Teddington Locks, whilst the River Lea, above the highest point of the East London Waterworks' intake, has only about 500 square miles.

Rain Clouds, How Formed.

Generally, cold winds blowing against warm mountains, or warm moist air. The moisture contained in the warm air is immediately condensed, first into a cloud, then into rain. At Table Bay and Table Mountain may be seen a good illustration of this. When the south-east wind blows over the mountain, it comes to the edge of the cliff, where it meets the warm moist air that is constantly rising from the bay. Here is deposited a constant supply of nearly pure water, which not only supplies the 45,000 inhabitants, but also numerous vessels which put in there for water. There, sometimes, the clouds are so heavy that the top of the mountain cannot be seen; this is known as the "spreading of the table cloth," and then look out for bad weather.

Water and Ice formed in Caves and Caverns.

Not far from Orenburg, Russia, the external summer air is met with at 90° in the shade, but the caves are so intensely cold that their roofs hang with icicles, which drip almost pure water on the floor, and again freeze. But in the winter the ice disappears, and the people then live comfortably within these caverns. Why is this?!! Because the caves occur at the bottom of the hillock formed of gypsum, where the evaporation produces cold, and this gypsum hill is traversed by numerous channels containing moisture, and in the summer time currents of air rushing through the cavities evaporate the water, which becomes colder.

Here the density of the water is increased and sinks lower and lower, and the more it descends the colder it becomes, and when the bottom of the cave is reached it is cold enough to freeze, and the hotter the external air the colder will be the cave. Why? Simply because the evaporation is more rapid or intense. In the winter season the action must be the reverse. Similar ice caves may be found in many other parts, especially in Switzerland.

Rain Statistics.

Having seen the number of square miles of earth to give or to assist the supply of the Thames, we will see about what quantity of water we should be able to get per year at the following calculations. An inch of rain falling on a surface of one square mile will give you 16,000,000 gallons of water, and as you have 3,500 square miles to assist or for the supply to the Thames, you here get 56,000,000,000 gallons, which on being multiplied by 22, the least possible average amount of rainfall, we arrive at the alarming amount of 1,232,000,000,000 gallons for the Thames alone. Then you have the Lea, whose intake area is 500 square miles; this will produce another 176,000,000,000 gallons, and the two together brings up the very respectable sum of 1,408,000,000,000 gallons (one thousand four hundred and eight trillion gallons), and taking a square mile at 1in. deep to weigh 140,200,000 pounds, equal to 72,200 tons, which multiplied by the 4,030 square miles equals 288,000,000 tons, and again multiplied by the 22in. (the depth of water for the year), we get 6,336,000,000 tons (six trillions three hundred and thirty-six millions of tons). But you must not expect to get this alarming amount of water into the rivers, as a proper allowance must be made for evaporation, which is explained in another part of my writings (refer to page 366), where I have said the evaporation is equal to the rainfall on a *free surface*, but as these lands draw the water, and assisted by gravitation, below the surface, it remains no longer free, owing to the porosity of the ground, when you get in time about three-fourths into your river.

The mean daily flow down the Thames in the driest seasons at Teddington Weir is about 500 million gallons, and the quantity abstracted daily by the metropolitan water companies can be seen by the Tables, but the maximum quantity which these water companies are allowed to take by the Thames Conservancy people, &c., in the twenty-four hours is 130 million gallons.

Now, supposing we should have, say, six months' dry weather, viz., without any rain, a casual observer would say then a water famine would be the result; but this is not so, for the following reason. You have already seen that we have 3,500 square miles above the Thames where rain water falls: now this water penetrates on what is known as permeable formations, which foundation or bottom is clay, or other impervious material, and the detention of the water by the oolites of chalk resting above acts as an enormous never-failing reservoir, which oolites, viz., chalk, sand, and gravel, receive the water middling rapidly, but yields it slowly to the banks and bottom of the river, and thus though we may be months without rain, the river still flows; and indeed it is only when these oolite beds are fully charged, or being charged too rapidly, that we are troubled with floods, and hence greater impurities of the water after floods than generally.

The tributary streams in the gravel, sand, and chalk district are almost unknown to the ordinary reader, but form an important item in the Thames water supply.

Now the great talking or twaddling question about the water companies of to-day (leaving out casualties of frost, overabundance of sewage, and such-like, the latter of which will be treated hereafter) by the average would-be laconic is, Should we have an exceptionally dry summer, where are we to get our water from? But this is really not the question, and it is a subject which is not, even by some of my fellow workmen, who should know better, generally understood. The real question is a matter of storage, and proper and adequate pumping machinery, with the plumbing trade to assist in giving attention and rectifying all undue waste (the plumbers I am warranted in saying could save fully one-eighth the daily supply), and the water companies to amalgamate and at once set about to bring us sea-water from the Nore for our streets and baths. This is what I wish to see.

Water storage, as before said, forms a most important part in the supply to London, not only for dry summers, but also during freshets or stormy seasons, for you must know that the time of taking water into the reservoirs should be when it is in good condition, viz., bright and clean, of which we only get on the average 250 days, and about another 50 days moderately discoloured, and the rest of the year, viz., 65 days, is, on the average, exceptionally turbid and muddy; and, it must be remembered, that if you take water in on these muddy seasons, that your filter beds and chemical impurities will be in accordance.

Perhaps it has not occurred to you to examine my London Water Companies' Supply Table for the amount of storage. There you will see the East London with their 615 million gallons, whilst the New River, which is nearly as large, have very little more than one quarter. True, the New River do not depend upon the Thames; but they cannot do without the River Lea water, which they get from the river near Ware, in Hertfordshire, and convey by a canal, or cut, into Sir Hugh Myddelton's roundabout canal known as the New River, and into which the Chadwell Springs and a lot of the artesian wells' water get mixed up before they reach London. The other companies are similarly situated, excepting the Kent, which, I suppose, are better off than all the others, as they take theirs first-hand from the chalk beds, the very life of the London water-bearing strata.

These areas must not be considered as the only sheds which these water companies have, for they have amongst them fully five hundred acres of deposit reservoirs, besides a quantity of other reservoirs full of filtered water, below the filtering medium. For instance, though I have given Lambeth credit for having twelve acres of filters, it must not be considered that this represents by any means the extent of their filters, or the 128 million gallons to be the outside limit of their supply, for these people (and many others in proportion) have 36½ acres of subsidence reservoirs and 31 acres of filter beds at Thames Ditton. They take 20 million gallons of water per day from the Thames at West Molesey, where they have two reservoirs holding 125 million gallons. At this place, West Molesey, the water is considered to be very good, from where it runs to the filter beds at Thames Ditton, by gravitation, and passes three feet of coarse gravel, one foot of shells, and three feet of sand. They have, at this latter place, engines amounting to 2,220 horse-power, capable of pumping 30 million gallons of water per day, at the expense of 30,000 tons of coal per year.

We have seen that they can pump 30 million gallons in a single day, and when it is understood that the London daily average water supply is near enough for 200 million gallons, and that this would fill a reservoir 50ft. wide, 10ft. deep, and over twelve miles long, it is something to think about, more especially when one calls into mind the fact that this water is distributed through 5,000 miles of mains, varying in size from 3in. to 42in. in diameter, and that there are 1,351 miles of streets under the constant supply, or 75 per cent. of the houses, and that these water companies' districts extend from Sunbury on the west of London to Greenhithe on the east, and from Croydon on the south to Waltham Abbey on the north, the area of which contains at least between five and six millions of people, besides hundreds of thousands of horses and cattle. Averagely speaking, we get 54 per cent. of the water from the Thames, 30 per cent. from the River Lea, and 16 per cent. from wells and springs; but if this is wanted accurately consult my table. Roughly speaking, it is generally understood, and no one on earth, as things now stand with the water companies, can tell definitely thirty-two gallons of water per day is used by each

in and about London, and I very much question whether twenty gallons are *legitimately* used by each person, and if one pint, on the average, per each person is consumed in an unboiled condition for drinking purposes, this leaves a big margin, for baths, which may be safely taken at not more than ten *fixed* baths to every hundred houses, to the great shame and disgrace of the London builders.

It will now be time to examine where the East London get their *various* supplies from. I have said that they get a supply from the River Lea; well, this is close to Chingford Mill. The water then gravitates into immense settling tanks, having a capacity of nine million gallons. They have also chalk wells at Chingford, Walthamstow, Waltham Abbey, Lea Bridge, and also take ten million gallons per day from the Thames at Sunbury.

FLUCTUATION OF THE LEA.

I don't wonder that the East London Water Works Company sought the Thames as a more reliable source for their supply, considering the erratic flow of the Lea; for what do we find in the table? In January, there is 190 million gallons running; in February, 280 million gallons; whilst in September, the time when most wanted, it is down to 50 million gallons, and a mean average of about 109 million gallons; so that if the New River should take, we will say, 10 million gallons a day, and the East London, which they want now, 40 million, here is the whole of the water for the September month: and this assumes a very grave point, and one which should be at once rectified by fresh grants of cash for new and capacious storage reservoirs, by hook or by crook, *and salt or sea-water for road watering. This is the thing to do.* It has been said, and by very high authority, that the New River and East London Water Companies, to supply their districts in the four successive driest months, require as much as 86 million gallons daily, which assumes a very serious aspect, considering that there are 2½ millions of people in the East and North of London which should be supplied from the Lea and the water stored in the underground reservoirs.

RIVER LEA LOCKS.

It must be remembered that the water companies cannot expect to have all this available water, as the Lea Conservancy people require 2½ millions of gallons daily to work their locks during July, August, and September.

Natural Reservoirs and Filtration.

The Thames Valley is a composition and conglomeration of deposits of gravel, sand, and loam. The banks and the slopes of the river are, in places, of considerable depth. For this take a trip from Hammersmith to Maidenhead, when you will have a chance to see Thames Ditton and Molesey; and, if you could walk below the earth, you would find at least 150 square miles of natural water reservoirs all acting more or less as natural filters.

They receive land water from the higher points, and also the water from the floods, the water of the latter being fully charged with mud; and when the tens of thousands of acres are covered by these floods, collect the mud therefrom to enrich the pasture, and so the water becomes filtered. When the river is low pure water pours back into the river in abundance.

WATER COMPANIES AND NATURAL FILTRATION.

There has been a good lot of spirit put into this subject of late, so much so that several water companies have constructed large works, or collecting conduits, by laying earthenware pipes with open joints, underground, to convey the river water to the natural gravel and ballast beds, where a natural filtration of the water through these beds, and to a kind of sump or made reservoir, takes place.

The Grand Junction, East London, Lambeth, Chelsea, Southwark, and Vauxhall are the companies, and, as simple as this looks, from a dozen to eighteen million gallons of water each is now collected in this manner daily. Doubtless, you will say that these distributing pipes in course of time will become fouled by the dirty water, and therefore sluggish in action, and would be very difficult to cleanse. Quite right; but such experienced engineers as Mr. Fraser of the Grand Junction is not to be baffled in this manner. He has, to get over this point, adopted another plan by extracting the surface soil and gravel to a depth of several feet over the intended natural filter and placing thereon a layer of sand from twelve to eighteen inches thick, which collects the principal deposits upon its surface; this can be easily lifted and carted away, so that the natural filter is perpetual to the made wells. From what I have said and shown by Fig 959A, the subject will be easily understood. This is one way of assisting to give a daily supply to London of the required 152,026,704 gallons, or thereabouts, of domestic water, to say nothing of the other 38,006,675 gallons for non-domestic purposes. And something of this kind must be adopted, considering the average yearly increase in demand, which the following table illustrates. Remember, on the average, we take daily from the Thames 103,466,816 gallons, and from the Lea 52,371,230 gallons, and 34,095,470 gallons from springs and wells, besides the Highgate and Hampstead supply of 99,863 gallons for non-domestic purposes.

EAST LONDON WATER WORKS.

Year.	Daily supply.	Increase on previous year.	No. of Houses supplied constantly for 1893.
1883	32,855,813	440,173	
1887	35,145,631	—	175,106
1893	40,856,228	344,247	
	NEW RIVER.		
1883	28,369,711	728,134	
1887	30,019,389	860,444	91,977
1893	37,345,800	2,683,450	
	SOUTHWARK AND VAUXHALL.		
1883	18,851,789	386,124	
1887	22,139,003	1,082,088	99,443
1893	28,371,130	2,163,185	
	LAMBETH.		
1883	15,764,209	48,688	
1887	18,208,134	625,717	59,887
1893	21,213,016	1,342,712	
	GRAND JUNCTION.		
1883	13,419,481	253,275	
1887	16,427,514	36,683	58,771
1893	18,771,164	179,996	
	WEST MIDDLESEX.		
1883	12,263,029	721,346	
1887	15,035,556	244,046	43,628
1893	18,716,776	1,274,803	
	KENT.		
1883	8,899,921	750,284	
1887	11,292,608	217,438	48,508
1893	14,393,701	1,475,102	
	CHELSEA.		
1883	8,899,[illegible]	7,440,279	
[illegible]	[illegible]	—	18,757
[illegible]	[illegible]	[illegible]	

The above is not all which has to be considered; for from 20 to 30 per cent. in addition will be required to be added to the daily supply during prolonged drought or frost after the constant supply is given, unless the following be strictly observed:—

Constant Supply.

Speaking of the constant supply, there is no doubt but what this is the best way to supply water to towns. But this necessitates a thoroughly well-constructed system of fittings, and periodical house to house examination or inspection by a qualified and recognised waterworks man, and the establishment of heavy fines on the water waster, to prevent wilful waste. And when the fittings are properly constructed, with proper cisternage, and the people educated to appreciate the advantages of this constant supply, I verily believe it will be the cheapest in the long run. But let us have a system whereby the consumer can at all times, winter or summer, ensure sufficient water for culinary and drinking purposes. The best way to ensure this is to re-model the pipes within the houses, by fixing first the mains so that there will be a gradual fall from the cistern towards the stopcock, and a draining pipe or cock to allow the dead water to drain out in times of frost. There should also be a second stopcock nearer to the main, called the main stopcock, and a drinking draw-off pipe and cock fixed between the two stopcocks. The advantage of these cocks will be readily appreciated in the winter, as the second stopcock, which governs the upper cisterns, can be closed and the emptying or draining cock opened, so that this main cannot freeze; whilst the drinking or draw-off cock and pipe, which is generally in the basement part of the house, can be well protected by straw, &c., without being an eyesore. The pipes from the cisterns should also be laid to empty themselves systematically, and where pipes are really of necessity bound to be kept filled, such pipes should receive proper attention against frost; and no one should be allowed to fix any pipes *summer or winter* unless fully protected against frost; and the waterworks companies' people should be held responsible for such provisions being properly carried out; and anyone interfering with the pipes so laid, or by adding thereto without the company's consent, should be punished with great severity.

N.B.—When speaking of the above stopcocks care should be taken to fix them so that the whole of the water can *drain out*, viz., all screw-downs should be fixed upright or with the spindle towards the earth, or the reverse to what is now generally the practice. This is of vital importance for frosty seasons.

Cisterns and Constant Supply.

The reason why I would have cisterns in a house is to meet the requirements of the excessive drain upon the companies' pipes between seven and twelve in the morning, and as a provision against accidents and repairs, alterations, &c., in the street mains, for it would be an extraordinary affair if there should not be some little matter requiring an occasional shut down, and here is the advantage of the cisterns. Now, these cisterns may be objected to, as a source of stagnated water, and collectors of sediments. But this is no fault of the cistern, but a fault (if any) of those who fix them, by making them too large, or of those who look after them. These cisterns should have a periodical inspection from what I would call the waterworks' inspector, who should leave orders when required for cistern cleansing. Another way to get over this assumed difficulty of stagnated or dirty water is to fix cisterns of the shape of air vessels, similar to Figs. 801 at R, 802, or 944. These need not be made very large, and could be fixed in the cellar, or in any out-of-the-way place, a suitable valve with strainer in front being fixed, to prevent the water running back into the mains. If such reservoirs be fixed care should be taken to provide a sluice valve in the bottom to draw off all sedimentary matter at intervals. (Also see Cylinders for Constant Supply.)

WATER COMPANIES' HEIGHTS OR PRESSURES.

Some would say, But what a tremendous and powerful air chamber or vessel you would require to withstand the following pressures. The East London have to keep a pressure of 40ft. above the level of pavement nearest to the point of supply; the New River 300ft. above Trinity high-water mark, or 70ft. above the pavement opposite the house supplied; the Southwark and Vauxhall must maintain a water pressure of 150ft.; the West Middlesex 200ft. above Trinity high-water mark; the Chelsea, to the parts where their supply is constant, have to maintain a pressure of 148ft. above Trinity high-water mark; the Grand Junction 150ft. above Trinity high-water mark; the Kent Company must maintain a head of 180ft.; the Lambeth 150ft. above Trinity high-water mark.

EAST LONDON WATER COMPANY.

The East London are providing their customers within the metropolitan area (and a large portion of their extra-metropolitan area) with a constant supply.

GRAND JUNCTION WATER COMPANY.

The Grand Junction Water Company have voluntarily introduced the constant supply to their customers who are situated in the parish of St. James's, Westminster, bounded on the west of Regent Street, east of Poland Street and Windmill Street, north of Oxford Street, and south of Piccadilly; also in the parish of Marylebone, between Oxford Street and Edgware Road; also west of Queen's Road, Bayswater, and Paddington; and part of Kensington, Chiswick, Acton, Ealing, Hanwell, Isleworth, Twickenham, Heston, Brentford, and Hounslow.

KENT WATER COMPANY.

The Kent Water Company provide a constant supply to the whole of St. Mary's, Woolwich, St. Paul's, and also St. Nicholas, Deptford, St. Mary, Rotherhithe, St. Alphege, Greenwich, St. Mary's, Lewisham, St. Giles', Camberwell, St. Margaret's, Lee (Kent), Eltham, and sections of the county districts, of Shortlands in the parish of Beckenham, Dartford, Stone, the Gray Valley, Swanscombe, Erith, Bromley, Chislehurst, Hayes, Farnborough, Keston, Sidcup, &c., on the Kentish side of the water.

LAMBETH WATER COMPANY.

The Lambeth Company are giving a constant supply from New Park Road, down Brixton Hill to Water Lane, and to Herne Hill, and the constant supply districts are within the parishes of Lambeth, Newington, Streatham, Tooting, Camberwell, Christchurch, St. George the Martyr, Clapham, Wandsworth, Battersea, St. Saviour's, Bermondsey.

THE NEW RIVER COMPANY.

The New River Company are giving constant supply about the parishes of Shoreditch, Edmonton, Stoke Newington, Hornsey, Tottenham, St. John's, Hackney, St. Luke's, Middlesex, Clerkenwell, St. Pancras, Cripplegate Without (which is in the City of London), St. George's, Bloomsbury, St. Giles-in-the-Fields, St. George the Martyr, Liberty of Saffron Hill, Gray's Inn, Furnival's Inn, St. Andrew's, Holborn, Holloway, Highgate, Colney Hatch, Wood Green, &c., &c.

THE SOUTHWARK AND VAUXHALL COMPANY.

The Southwark and Vauxhall Company are giving constant supply round St. Mary's, Newington, St. George the Martyr, Southwark, St. Saviour's, Southwark, St. Mary's, Lambeth, St. Olave's, Horselydown, St. Giles', Camberwell, St. Mary's, Bermondsey, Wimbledon, St. Mary Magdalen, Bermondsey, St. Paul's, Deptford, St. Mary's, Rotherhithe, St. Mary's, Battersea, All Saints', Wandsworth, Holy Trinity, Clapham, and Putney.

THE WEST MIDDLESEX WATER COMPANY.

The West Middlesex Water Company give constant supply to many of the places in Marylebone, which lay between Lisson Grove and Edgware Road, Cleveland Street, Hampstead Road, Tottenham Court Road, Kensington, Fulham, and Hammersmith.

The General Dimensions of the London Waterworks.

The magnitude of these water companies is enormous. The aggregate surface area of 53 subsiding reservoirs for unfiltered water is, at least, 500 acres, with a storage capacity of nearly one and a half trillion gallons, and a storage of filtered water for about 220 million gallons, which is held in between 60 and 70 reservoirs, 58 of which are covered. There are close on 25,000 hydrants, and nearly 124 filter beds.

There are 190 pumping engines of about 25,000 horse-power.

The East London have recently acquired 222 acres of land for reservoirs, to hold unfiltered water, besides 10 acres of private river or canal. The total capacity of the reservoirs and the canal will be about 920 million gallons, of which 620 million gallons gravitate to the filters of Lea Bridge. They have other large works at Walthamstow.

The West Middlesex are making four new storage reservoirs at Barnes, of immense magnitude, namely, capacity 350 million gallons. They are about to purchase, or have already purchased from the Grand Junction Company a service reservoir at Shoot-up-Hill, which holds six million gallons, together with the 24in. main.

The Grand Junction have a Worthington pumping engine at Hampton, raising three million gallons in 24 hours; they have also large works at Brentford.

The New River have immense premises, and have just fitted up a new Worthington engine of 250 horse-power at Hornsey, besides further enlargements of their river, and widening the bridges.

The Lambeth have just fitted up a Worthington engine which at every double stroke pumps 310 gallons, and are making good progress with new filters at Thames Ditton, besides having just laid a 36in. main from Molesey to their filters at Thames Ditton.

The Southwark and Vauxhall Company are about to utilise the Streatham well, and have fixed appropriate engines there within the last twelve months.

The Chelsea Company have just laid a 24in. main, three and a quarter miles long, to supply their reservoir at Putney Heath, from Stamford Bridge, Fulham.

All the London water companies have extended their pipes during the last two years, and taking them together, they have managed to lay 72 miles of new supply pipes, averaging from 3in. to 36in. diameter, so that, taking all into [illegible]ideration, you see we are progressing. The water [illegible]nies gen[illegible] deepening their mains against

Hydrants.

The following are the numbers which each company has, to say nothing of fire plugs, which are about one in every hundred yards.

East London 2,223, New River 600, West Middlesex 250, Grand Junction 900, Kent 70, Lambeth 150, Southwark 400, Chelsea 150.

Turbid Water; or, better, Muddy Water.

Muddy water may have to be drunk in some parts of the world, and will not hurt you half so much as some of the clear water of our rivers. Of course, if you take the common dictionary definition of the word "turbid," it alludes to foul extraneous matter, and may allude to filthy clear water, but this is not what is generally understood by water drinkers as turbid water. Water from wells containing chalk are easily made turbid by boiling, especially if a little soda or even any other alkali be added. Even the streams of the Alpine glaciers are turbid enough to prevent one seeing through a 4in. diameter bottle, which is much worse in times of floods. The best way to get rid of this is in settling tanks, for if it is allowed to get into the filters it will in a short time choke your filter material at the surface.

Stinking Water, by some people called Turbid Water. [*Also see Micro-Organisms.*]

Filtered and, much more so, unfiltered water is apt (especially in hot weather) to acquire, by standing, a faint, unpleasant odour, resembling that of the farm-house ponds, where no springs or streams exist, and to a delicate palate is most offensive, even if not detected by the olfactory nerves. Now this taste or odour is due to the fact that the water is contaminated with some chemical, but more often the growth in it of microscopic forms of animal life, the eggs or germs of which it is simply ridiculous to look for without the assistance of a powerful microscope, and, even then, without a certain amount of bacterioscopic knowledge; in fact, I have seen good analytical chemists at work, one against the other, and their results have varied from 10 per cent. to 25 per cent. with the same water and instrument. Why is this? Simply because the seeds, spores, eggs, or germs are so infinitely small that it is almost impossible to exclude them floating from the air into your work; and when such is the case the water is often credited with a larger amount of animalculæ than it should be.

To prove this take a dish of pure water and expose it to the common warm atmosphere and sun for a few days, and in a very short time the water will be full of animalculæ, known as rotifers. Many of these are, at times, large enough to be seen, but only just seen, by the naked eye. They appear to be always struggling against each other, especially when one class gets mixed with another, hence one reason why I have called them herbivorous and carnivorous devils, for they appear to live on each other. But the question is, What do they find to live on in the distilled water? True, we know that they are fond of vegetable, such as it is, or say the very minute portions of the various substances which are dissolved in the water and incapable of being separated from it by mechanical means, or distilled water after being exposed to the atmosphere; and that they, like all animal life, are found simultaneously created by the author of Nature, or at one and the same time, and in every part of the animal kingdom. Many are the ways to produce stinking water. Take an ordinary aquarium, whose bottom is covered with washed pebbles and sand, plant therein a sprig of thoroughly washed *Vallisneria Ranunculus*, *Aquaticus* or

Anacharis (water-weed), and in a week or so after add a young fish, or other water animals, both will grow, but keep the water unchanged, the fish will die, whilst the weed will in time fill the aquarium, and even if you constantly change the water the fish will die. This is exactly what takes place if filtered water is stored too long in open reservoirs, and proves my assertion that filtered water should be used as quickly as possible after filtration, and that storage reservoirs should be simply used for storing the water and getting it clear by *settlement* and ready for filtration.

In point of fact, the general drinking water of London will not keep, owing to the above contamination; but, of course, if it were possible to get perfectly *pure* water, it would keep for ever, for then, should any germ, spore, or seed get therein, the water would contain nothing for it to feed upon;

Water, the Gnat, and how Water gets Contaminated.

Just so, but how about such things as the common insects, say the ordinary gnat, who lays her eggs in a mass on the surface of specially selected good water, the eggs of which would readily sink if separated out, but owing to a glutinous substance the whole mass is held together, shaped like a boat, and practically unsinkable, until the grub is formed. This grub then leaves the egg and at once commences to swim about at an extraordinary rate head downwards and with its tail in the air. The tail contains a spiracle through which the breathing is carried on. First we had the egg, then the glutinous substance, next the insect, and for the fourth stage (third, really) we get the nymph or a kind of chrysalis, a beautiful creature wrapped in a kind of veil, which insect floats in our water, near the surface, the tail of which is its rudder, and two terminal organs its paddles; whilst the back of the gnat is really in the air, through which organ it seems to breath. Next we get in our water the chrysalis-case, though empty yet it is a substance in which animal life existed; it floats at first, then breaks up, and mingles with the water we have to drink. This is only one way out of thousands in which this necessity of life becomes contaminated.

The Quality of Water.

We will now examine the London water for its purity, and the following table will give an approximate return before and after filtration, which requires but little explanation.

By observing the top line of the Chemical and Proportional Table figures you will see a tremendous jump between January, February, and March. There is also a sudden shoot up in October, also see September and November, but nothing like that of February. This is accounted for in the Volume Table for February, when we had tremendous floods all up the River Thames, and they seem to have had it pretty fairly in the River Lea, where they get 280 million gallons daily over the weir, and a greater amount of rainfall during February than any other month in the year. The table, being so simple, can be readily understood by people outside the trade.

By observing the River Thames, also the River Lea, in the January, February, and March Tables for the Solids in the 100,000 Parts, you will find during this flooding time the greatest amount of deposits, which is the reverse of that of the East London deep wells, which during April, May, June, July, and September is the greatest, whilst the ammonia in the water of the Thames and River Lea is greatest in the month of January. But in the Tottenham wells the greatest amount of ammonia is in December, April, March, February, and January, whilst the lime in the Thames water is greater in January and March, but in the River Lea in January, February, October, and December. The chalk and lime from the Thames water appears to be in January, and in the deep wells of Kent and Tottenham in January and December. The carbon abounds in the Thames water more in February and March than any other month. This is owing to the excessive flooding. It is also the same in the Tottenham deep wells.

CHEMICAL AND PROPORTIONAL TABLE.

Chemical and Proportional Quantity of Organic Elements in Raw or Unfiltered London Water. Taking 0 as the starting point, and without organic matter. The takings being the 15th of each month of 1893.

	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Thames Water at Hampton.—Organic Elements	3·0	9·9	3·2	3·1	3·1	4·7	4·5	3·8	3·7	6·6	3·6	3·8
Weight of Solid Matter in 100,000 parts of Water unfiltered ...	33·50	34·0	30·50	27·50	27·50	27·0	26·50	25·0	25·50	27·0	28·50	32·50
Thames Water after Filtration in London	3·0	6·4	6·2	2·1	2·3	2·5	2·2	2·4	1·9	2·6	2·6	3·1
Lea Water (Raw) at Angel Road...	4·7	5·3	2·4	2·8	1·8	4·4	3·0	2·7	2·6	4·0	2·8	4·3
East London, Weight of Solids in 100,000 parts	39·70	35·0	38·0	31·50	27·0	28·25	26·50	26·25	25·15	29·0	31·0	35·50
Lea ,, ,, ,,	33·25	35·30	30·50	28·50	30·80	32·60	31·85	28·0	30·15	33·45	32·50	34·80
,, Water after Filtration in London	3·0	5·7	4·4	2·0	1·8	1·9	1·9	1·5	1·9	3·1	2·2	3·0
New River Water (Raw)	2·5	4·5	1·7	2·0	1·6	2·1	1·9	1·9	1·9	·1·9	1·5	1·5
,, after Filtration in London	1·6	1·8	3·4	1·2	1·2	1·3	·7	1·1	1·0	1·2	1·0	1·9

Weight of Solid Matter in 100,000 parts of the Water.

	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Kent, Deep Wells Water	40·50	41·0	41·50	[illegible]	[illegible]	37·50	40·15	39·0	39·25	39·50	37·25	55·50
East London, Deep Wells Water...	28·25	28·50	29·0	[illegible]	[illegible]	[illegible]	39·0	29·0	38·50	29·15	29·25	28·50

CHEMICAL AND PROPORTIONAL TABLE—*continued.*

	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
AMMONIA.												
Ammonia in Thames Water, unfiltered	·020	·008	·006	·006	·006	·020	·006	·004	·006	·010	·006	·012
„ „ Lea River „	·014	·008	·002	·006	·004	·008	·006	·006	·006	·006	·007	·006
„ at Tottenham, Deep Wells	·060	·060	·065	·070	·060	·055	·048	·045	·050	·055	·025	·082
HARDNESS FROM LIME AND CHALK.												
Thames Water, Hardness, Carbonate of Lime, 1 deg. = 1 part in 100,000 parts of Thames Water	24·0	20·5	23·5	20·0	19·4	20·0	18·5	18·0	17·4	18·0	20·0	20·6
Lea River	24·9	24·0	22·0	20·6	21·6	22·6	20·0	19 0	20·0	24·0	22·5	23·4
Kent, Deep Wells	30·0	29·0	28·0	29·0	27·0	27·0	28·0	27·0	26·0	26·6	26·6	31·6
Tottenham, Deep Wells	24·8	23·5	22·0	22·6	23·0	22·4	22·0	23·0	23·5	23·0	22·0	23·3
ORGANIC CARBON IN 100,0 0 PARTS.												
Thames Water, West Middlesex...	·120	·310	·317	·100	·100	·133	·117	·120	·095	·103	·130	·155
„ „ Lambeth	·230	·350	·365	·123	·120	·140	·095	·120	·100	·160	·140	·160
Lea, East London	·145	·303	·200	·100	·080	·095	·095	·075	·095	·156	·110	·150
New River	·075	·080	·170	·060	·060	·064	·030	·054	·045	·060	·052	·104
Deep Wells at Tottenham... ...	·065	·065	·066	·048	·060	·060	·060	·038	·037	·083	·084	·046
Kent, Deep Wells	·036	·033	·014	·026	·040	·021	·034	·040	·024	·020	·032	·070
NITROGEN (NITRATES AND NITRITES) 1 PART IN 100,000.												
Thames Water, West Middlesex...	·330	·250	·240	·230	·164	·151	·145	·120	·145	·194	·204	·263
„ „ Lambeth	·264	·255	·335	·230	·190	·184	·146	·152	·157	·222	·233	·260
River Lea, East London	·330	·252	·440	·306	·182	·184	·196	·184	·142	·196	·260	·260
New River	·310	·300	·296	·339	·186	·184	·140	·163	·193	·230	·274	·326
Kent, Deep Wells	·445	·500	·520	·458	·470	·500	·529	·440	·469	·440	·515	·770
ORGANIC NITROGEN 1 PART IN 100,000.												
Thames Water, Lambeth	·036	·056	·062	·016	·013	·016	·010	·014	·013	·020	·020	·019
„ „ West Middlesex...	·024	·040	·050	·019	·011	·016	·016	·016	·016	·010	·014	·016
Lea, East London	·033	·036	·044	·016	·014	·011	·016	·010	·014	·020	·014	·021
New River	·016	·020	·030	·007	·007	·011	·011	·009	·006	·006	·011	·010
Kent, Deep Wells	·019	·009	·009	·004	·004	·004	·006	·007	·008	·008	·005	·012
NITROGEN 1 PART IN 100,000.												
Thames Water, Grand Junction...	·310	·310	·256	·250	·176	·172	·166	·180	·170	·230	·240	·270
„ „ West Middlesex...	·350	·296	·290	·240	·170	·166	·154	·136	·166	·210	·221	·282
Lea, East London	·360	·290	·486	·320	·200	·196	·214	·196	·156	·220	·280	·284
New River	·340	·320	·324	·336	·190	·189	·146	·170	·200	·236	·282	·329
Kent, Deep Wells	·460	·500	·530	·450	·480	·511	·536	·445	·480	·450	·520	·784
CHLORINE 1 PART IN 100,000.												
Thames Water, Grand Junction ...	1·9	1·7	1·7	1·6	1·6	1·6	1·6	1·6	1·6	1·8	1·8	2·0
„ „ Lambeth	1·8	1·6	1·9	1·6	1·6	1·8	1·6	1·8	1·8	1·8	1·8	2·1
„ „ West Middlesex ...	1·8	1·6	1·6	1·6	1·6	1·8	1·7	1·6	1·8	1·8	1·8	2·1
Lea Water, East London ...	2·0	1·6	2·3	2·1	1·7	1·6	1·8	1·6	1·7	2·0	2·0	2·1
New River	1·7	1·6	1·6	1·9	1·9	1·9	1·7	1·6	1·8	1·9	1·6	1·8
Kent, Deep Wells	2·5	2·6	2·4	2·4	2·4	2·3	2·6	2·1	2·3	2·1	2·2	4·2

I have designed the above Table to save space. The results are from my practical observations during the 12 months of 1893.

Microbes and Fever, or Cholera Bacillus.

The cultivation of these devils appears to be favourable in river water; in fact so much so that during the year 1893 the average in the Thames water amounted in number of microbes, and in a cubic centimetre was 5,000, and the maximum 56,000 in the Lea. It is well known that these cholera germs are propagated by the agency of river water.

The malady seems to come to England from abroad, and especially from rivers that empty direct into the sea, having tidal streams, more especially should the river be a navigable one.

First the workman becomes affected with this bacterial impurity, generally by consuming portions of the water which to him appears bright, sweet, and good, and when he is once so affected this zymotic poison germ clings, generally till grim death overtakes the sufferer, or, if not death, the sufferer does not exactly know what is the matter with him, but goes in for a rest amongst his pals, often not of a very quiet character, but to public-houses where they go in for their beer, and often drink out of the same vessel, glasses, &c., and in a few days the whole place is a hot-bed of typhoid or other fever; often the whole town becomes a place of choleraic dejections.

VOLUME TABLE.

Volumes of Water in Million Gallons drawn daily per month during the year 1893.				Thames overflow at Teddington Weir, daily average per month of 1893, in Million Gallons.	Lea River overflow at Fielder's Weir, daily average per month of 1893, in Million Gallons.	Rainfall in inches in London Water supply during 1893. This was about 22% below the average.	Microbes in one Cubic Centimetre of Water. Open Thames Water at Hampton, Approximately.	Grand Junction Natural Gravel Filter Bed, and Wells at Hampton, before spoken of, Thames Water.	Artificial Hampton Filter.	New River.	Lea, East London, at Old Ford.	Lea, East London, at Old Ford, after fourteen days Storage.
	Thames. M. Galls.	Lea. M. Galls.	Springs and Wells. M. Galls	M. Galls.	M. Galls.	Vertical ins. deep.						
Jan. ...	101·5	59·7	35·0	1,651	190	2	8,000	80	6,000	31,000	56,000	1,200
Feb. ...	95·5	52·2	30·1	3,021	280	$3\frac{1}{3}$	4,000	40	420	2,000	6,000	1,350
March .	93·3	54·0	28·6	2,250	173	$\frac{1}{4}$	13,500	45	1,300	500	2,250	350
April...	99·8	55·6	31·8	910	100	$\frac{1}{8}$	1,500	40	500	500	2,500	450
May ...	110·2	54·0	36·4	610	77	$1\frac{1}{5}$	2,000	300	300	2,000	3,000	—
June ...	113·2	53·4	41·2	447	60	1	2,500	20	180	2,000	4,000	—
July ...	111·0	50·3	38·8	357	60	$2\frac{7}{8}$	2,300	20	200	4,000	8,500	1,200
Aug. ...	110·9	50·5	41·5	357	60	$1\frac{1}{3}$	2,000	10	200	1,500	6,500	—
Sept. ...	109·5	48·1	35·7	300	55	$1\frac{1}{4}$	1,000	9	100	1,000	3,500	900
Oct. ...	102·4	47·1	33·0	505	60	$3\frac{1}{3}$	13,000	60	90	2,250	5,250	500
Nov. ...	98·8	50·2	29·4	507	70	$2\frac{1}{4}$	1,500	70	150	2,000	8,000	900
Dec. ...	96·6	53·0	27·2	1,100	100	$2\frac{1}{2}$	6,000	30	258	4,250	11,500	1,360

From investigations of the highest importance, and from a hygienic point of view, it has been proved over and over again that our rivers are in a great measure responsible for all bacteriological fevers.

This being so it is of the utmost importance that a strict watch be kept upon the condition of the river water, and especially the filter beds belonging to the various water companies, for a great deal depends upon the condition in which they are kept.

They must be kept clean, save and except the too often removing of the nidus, which must be carefully avoided, and is of vital importance; the filtered water storage reservoirs should be kept covered over and as cool as possible, for these living devils do not like darkness nor especially the cold, and will not then multiply, especially if the water be near the freezing point.

They doubtless feed upon bad or stinking air, and readily float therein: but we are now dealing with our water, and to this let us keep. To prove that these devils prefer the warmth and light let us examine the water in the open Thames, especially in warm weather, say about the height of the summer, when as many as 14,000 microbes have been found in a cubic centimetre of water. Next take water abstracted from natural gravel and sand filters. There was an average of 5,000 in the open Thames water but only about 100 per cubic centimetre at the most in the water pumped from the wells of the natural filters of the same neighbourhood, and it is often much better than the open river water, even after filtration and passed through the companies' pipes. [For this refer to the Table of Microbes.]

Of course, if sewage is allowed to fall into the river, as is the case of the outfall at Hertford, which tells so hard on the Lea, the water below the outfall will of necessity be polluted more with bacterial germs.

Filtration appears to be the only practical way of dealing with these microbes, by way of removing them; perhaps I had better say catching them.

EAST LONDON.

The average percentage of these microbes removed may *be useful to you for* examinations, &c. The East London sand filters average 24in. thick, and one square foot will pass about 1·3 gallon per hour, and on the average will remove fully 90 per cent. of these devils.

NEW RIVER.

The New River sand filters average 20in. deep, and will filter 2·3 gallons per square foot in the hour. (This amount above the East London is owing to the depth of water above the sand, the state and closeness of the sand, and the difference in the thickness.) Their average percentage of devils removed is 98·80.

SOUTHWARK AND VAUXHALL.

The Southwark and Vauxhall Company's filters average 29in. thick, and filter at a rate per square foot of 1·5 gallon per hour, at the same time removing 98 per cent. of the devils.

GRAND JUNCTION.

The Grand Junction Company's filters average 21in. thick, and will pass 2·2 gallons to the square foot per hour, and remove on the average 97 per cent. of the devils.

WEST MIDDLESEX.

The West Middlesex Company's sand filters average 30in. thick, and pass 1·3 gallon per square foot per hour, and remove from 98 to 99 per cent. of the devils.

CHELSEA.

The Chelsea Company's sand filters average 48in. thick, and filter 1·70 gallon per square foot per hour, and remove on an average 98 per cent. of the devils.

LAMBETH.

The Lambeth Company's sand filters average 32in. thick, and filter about 2 gallons per square foot per hour, and remove 98 per cent. of the devils.

KENT.

The Kent Water Company obtain their water from the veins of the chalk wells, and do not require fliters, and are not much troubled with these devils; in fact, in the first two months of 1893 there were not more than two microbes per cubic centimetre.

It must not be considered that the best filters are in accordance with the thickness of the sand (see the New River, West Middlesex, and Chelsea). Much depends upon the regular rate of the working. Filters should not be allowed to run like sieves, but the water should gradually soak through about 4in. per hour, viz., 2·1 gallons per square foot, and not faster. I have two in my garden which give capital results at this rate; bye-the-by, frost must never get to the sand on the top of the filters.

The condition of the surface of the sand has a lot to do with results; for after the scum or thin film is formed on the surface of the sand the filter works better than before it is formed. This forms a kind of nest to harbour the devils, and should be carefully preserved, so long as the same will last clean, of course consistent with sufficient passage of water through the sand; and great care must be taken, when you scrape or clean off the before-spoken-of, now partly impervious, scum or nidus, to carefully examine the water when the filter is recharged; in fact, as a rule, it is best to pump the water over again for a time or two, and only have a few inches, say 3in., of water lying upon the sand for a few days, the bottom of the filter remaining full. When the scum cannot readily be obtained, from, say, a flood or something of the kind, about two or three grains per gallon of lime or alum mixed with the filter water and again passed over the filter beds, and allowed to settle for a few days, will soon put your filter in good working order.

Usefulness of Floods.

It is all very well for some people to talk about the inconvenience of floods, but you see our water supply to London at times, in a great measure, depends on these sources, though it brings with it myriads of microbes; but these floods are to the Londoners at times godsends, nor can the foreigners in some parts of the world get on without them. Take the Nile, for instance, which begins to rise in June and is from 24ft. to 28ft. deeper in August, when it floods the valleys of Egypt for about twelve miles wide. The Euphrates rises between March and June to 12ft., and covers the Babylonian plains.

Often seas and rivers, such as the Brahmapootra (bounded by the Himalayas), the Delta, &c., is of the flooding character. The mud, or silt, deposited on land is of great importance from an agricultural point of view. For instance, India depends for the fertility of the country upon the silt precipitated by the annual inundations, for the high lands yield crops only every four or five years, whilst the flooded lands yield perennially, the mud brought by the floods being—water, 1¼ per cent.; vegetable matter, 2½ per cent.; muriate of potash, ½ per cent.; carbonate of lime, 7½ per cent.; phosphate of lime, ½ per cent.; oxide of iron, 6 per cent.; alumina, 5 per cent.; and silex, 78 per cent. The high lands have not 1 per cent. of carbonate, which excess in the silt is ascribed to the fertility of the lower lands.

Where does the water from the Dead Sea (which has no living creature therein) go, considering there is no perceivable outlet, and that the River Jordan daily pours forth six millions and ninety thousand tons of water, to say nothing of rainfall collected? Allowing for evaporation there must be a tremendous leakage somewhere. Is it given up to us by way of springs? Certainly, we have such springs as Winifred's well, which flows at the rate of 120 tons per minute; but this is of rare occurrence, the River Jordan alone would supply about forty such wells, so, as I have said, Where does the water from the Dead Sea go?

Springs that flow from the limestone rocks deposit vast quantities of calcareous tuffa and sinter. Other springs deposit silica.

The surface of the globe is simply land and water; but it is not generally known that there are three parts of water to one of land. The water is, chemically speaking, made up of eight parts of oxygen and one of hydrogen; or by volume, one of oxygen and two of hydrogen, and possesses high power of chemical union and decomposition, and according to atmospheric pressure. It is estimated that the surface of the sea is 150 million square miles, and taking the surface of the whole globe at 197 million miles, the difference will be readily seen. Nor is it generally known that if the whole of the water could be spread to an equal depth over the face of the globe that it would be about two miles thick or deep.

The greatest depth of the sea is generally admitted to be about equal to the highest mountains, or about four miles; the average depth is, say, about three miles, and therefore contains about 450 millions of cubic miles of the 258,000 million miles of the whole globe.

The Pacific Ocean covers 78 million miles, and is four miles deep. It owes its name to its tranquillity, as the smallest vessel can ride it securely. It is a sea of corals.

The Atlantic Ocean has 25 million miles, with a specific gravity of 1·0282.

The Indian Ocean, 14 million miles.

The Mediterranean, 1 million miles, with a specific gravity of 1·0293.

The Black Sea, 170,000 miles, with a specific gravity of 1·01418.

The Baltic Sea has 175,000 miles.

The North Sea, 160,000 miles.

The Southern Ocean to 30° 25 millions miles.

Sea water contains, generally speaking, from 3·4 to 4 per cent. of salt. Its specific gravity is 1·028.

The Dead Sea specific gravity is 1·211.

The component parts may be generally taken to be water, muriatic acid, sulphuric acid, mineral alkali, lime, and magnesia. Our inland sea water is somewhat different. It contains in 1,000 parts—salt 25, sulphate of soda 3·3, muriate of magnesia 4·2, and muriate of lime 0·8.

The bitterness of salt water is only at the surface.

Salt sea water freezes at 28½° Fahr.

Geysers.

Some people may say, Where have all these chemicals come from? This is an unknown question. We must remember that we are only within a very short distance of what was once a fluid mass or ball of fire, and whose mass contains chemicals we know nothing or at least very little about, and if an ostrich egg should represent the earth, the shell of the egg would be too thick to represent the earth's crust, upon which all this water is suspended. This shell is cracked in places, and water gets too near the warm quarters, and is sent up middling sharp in the shape of geysers. (See the frontispiece, and Geysers, continued.)

Geysers, Thermal Springs, Gas Springs, and Volcanoes.

The increase of terrestrial heat is well illustrated as descend into the earth, and may be taken to be at rate of 1° for every 50ft. of strata pierced beyond 100 from the surface. In round numbers let us take

temperature at the surface of the earth as 50°. At the depth of one mile, say, 155½°, at two miles 261°, and at three miles, 366⅓°.

For our purpose we will say a depth of two miles is 250°. Here we have 38° above the boiling point, which, if this water was contained in a steam boiler, would produce a pressure of 38lbs. to the square inch—suitable for low pressure boilers; and, if the water came from a depth of three miles, we should get steam having a pressure of 130lbs. to the square inch.

Now the natural hot springs existing in various parts of our globe, issue from strata the depth of which one would be warranted in saying should correspond with the temperature of the water. If the temperature of the water issuing from such springs could be taken to be the same as that of the reservoir from which it has risen, such temperature should, approximately, give the depth of the reservoir; but you must remember that this water has to pass through certain strata which tend constantly to decrease the temperature, but how much decrease takes place no one is in a position to define.

Again, suppose this heat to be coming from a depth of three miles, it is just possible that this heat may not be in a liquid form. It may be that of a gas, or fluid only, piercing the upper portions of the earth's crust, and coming in contact with fissures of water, which is hurled forward as water from a steam injector.

Thermal springs appear, in some places, to be completely independent of the strata under which they rise. They do not exclusively prevail in volcanic regions. The hottest permanent springs discovered are those at considerable distance from volcanoes. Aguas Calientes de las Trincheras, between Puerto Cabello and New Valencia, in Venezuela, South America, had a temperature of 194½°, issued through a stratum of granite. Aguas Comangillas, near Guanaxuato, in Mexico, had a temperature of 205½°. Then, according to the assumption that 1° for every 50ft. is right, we get these last-named thermal springs from a depth of nearly two miles, but the deeper or hotter the springs are, the more erratic will be the flow, whilst those, such as the

Bath Springs.

(*Virtue discovered* 871 *years* B.C.)

Bath springs water, which is at the hot bath 117°, or of moderate temperature, are very constant. Neither does this constancy belong to the water itself only, but also to its chemical composition, which varies very considerably with, or according to the degrees of heat; and there is another thing which should be distinctly understood, that thermal springs within certain limits, of say from 109° to 160°, have never been known throughout Europe to have undergone the slightest change in their temperature or chemical analysis, whilst the hotter ones contain in solution varying proportions of mineral matter. For argument's sake take the springs of Las Trincheras, which, in 1800, had a temperature of 194½°, but in 1823 it was found to have a temperature of 206½°, or a rise in the temperature of 12° in twenty-three years. It is remarkable that springs, whatever be their temperature, the secular permanency nearly always attends them, and the fountains of Greece, which flowed thousands of years ago, to-day flow in the same places. Erasinos River, which rose in Stymphalus Lake, after flowing disappeared, but again sprung up out of the declivity of the mountain chain, about six miles south of Argos. Herodotus, the historian, mentions this spring, which to-day issues from the same slope of the mountain.

The Temple of Apollo at Delphi had a fissure in the centre of the building which gave intermittent vapour, supposed to proceed from the Cassotis Well, near by. This vapour was of an intoxicating character, which, according to the classics, made the Priest[illegible] Pythia drunk, and when in this state the oracle was consulted, and the words she then uttered were supposed to be a revelation of their God.

Curiously, Cassotis Well still exists, but is now known as St. Nicholas.

There are plenty of these classic fountains and thermal springs about Mount Parnassus, Pirene at Corinth, and Ædepsus on the coast of Eubœa near Chalcis.

It is strange to find these springs to remain with their subterranean waters unchanged for 2,000 years, in a country so peculiarly subject to such violent earthquakes as those before-mentioned.

Another example of a natural *jet d'eau* is at Lillers, near Calais, bored in 1126, or nearly eight centuries ago, supplying the same quantity of water.

I have said that it *may* be that these fountains, geysers, or whatever you like to term them, are probably caused by gases coming in contact with fissures, chasms, &c., containing water, but I will now, in order to substantiate this, delineate a few such ejections.

Various gases are ejected in enormous quantities from the lower regions in many parts of the globe. Some, of course, much stronger and larger than others. Sometimes the gas comes in the form of carburetted hydrogen (illumination gas), which is largely used at Ho-Tsing, in China. It is also used in the city of Khiung-Tscheu.

Then, again, there are abundant instances of gaseous ejections, from the interior of the earth, of carbonic acid, which have been running through its veins for thousands of centuries before animal matter could have been created. These fissures and crevices were nothing more nor less than the communication between the exterior and interior of this globe, and you may be sure that these fissures were more numerous and capacious than they are at the present time. The qualities of the gases which were then given off were very different to those given off to-day, and you may be sure that there was a large quantity of aqueous vapour always suspended in the air, which accounted for the exuberant vegetation of those times. This, to a certain extent, accounts for the vast forests of old, which, being fossilised, supply us to-day with inexhaustible stores of mineral and other fuel.

Speaking of this, there is an oil spring at Baku, called Assadoulayeff, which is giving something like 6,000,000 gallons of oil per day, and said to be worth £3,500 a day.

The prodigious volumes of carbonic acid supplied other purposes at the early period, by entering into combination with lime, which produced the marbles, which are nothing more than carbonate of lime, which is nearly half carbonic acid.

Air is rendered very deleterious by gases and vapours generated in the earth.

In a certain valley in the island of Java, carbonic acid is thrown out in such quantities that no animal can exist there, nor do birds live when flying low through the air above.

Then there are the volcanoes which eject hot mud, the earthquakes, the subterranean thunder, and the ejection of lofty jets of flame, which have been known to blaze to so great a height as to be seen at a distance of twenty-four miles, for three hours together. They would then fall back to three feet, and then blaze away for twenty hours, when up would come enormous lumps of rock and quantities of hot mud, which have produced such places as Monte Zibio, near Susuola, in the Duchy of Modena, and the Salse, near Girgenti, in Sicily.

Rock fragments, such as those which were ejected by Jokmali, are to be seen scattered around the former.

The Salse has continued in the secondary state of activity f[illegible] 1,700 years, consisting of cone-shaped mounds from [illegible]t. high, having small craters at the summit of the [illegible]h contain water, from which gas is disengaged;

but notice, the mud that is ejected from these volcanoes is cold. Sometimes these gaseous eruptions are attended with considerable noise, and give different kinds of gases at various intervals, sometimes carbonic acid, other times nitrogen, and then hydrogen, which is often mixed with naphtha.

Other craters, which are of a more energetic character in their subterranean force, will disrupt the floor of the crater by bursting holes or fissures therein, and thus a communication with the liquid fire, which fills the solid shell of the earth, when steam and acid gas will be ejected in vast quantities, after which it is followed by ignited scoriæ and red hot stones or fragments of rock, which will be followed by torrents of earthy incandescent matter of pasty fusion, known as lava, and here we have what is termed an active volcano.

There are several distinct stages of these volcanoes, nearly all of which more or less interfere with water supply.

Submarine Springs. Diving for Drinking Water.

It is not generally thought of, that there are springs of fresh water even boiling up in the bottom of large rivers and even seas.

Along the Persian Gulf there is a tract of country, perhaps the hottest region of the earth. The land is rarely refreshed by rain, yet this place is populated, and watered by numerous fresh water springs; and, strange, these springs are at the bottom of the sea, where the fresh water is obtained by diving, as follows:—

The diver sits with a companion in a boat. He takes a kind of bag, preferably made of goat skin; this he winds round his arm, holding the mouth of the bag closed. With the disengaged hand he throws a heavy stone overboard, which is attached to a line; the stone is allowed to fall to the bottom, he makes good the line to his boat, and then jumps overboard and pulls himself to the bottom, finds the spring, holds the mouth of his bag over the mouth of the spring, the bag fills, and up both come, he holding together the mouth of the bag, and is quickly pulled into the boat by his companion.

These springs travel the bowels of the earth for a matter of several hundred miles. Some say five hundred, whilst others say six hundred miles distant.

American Aqueduct.

I will just draw your attention to the American water supply for New York, which they had in working order so far back as 1842, and have increased it according to the growth of the city; so that they are not by any means behind other countries, although their place is of comparatively new civilisation.

Take the Croton aqueduct, which was commenced in 1837 and completed in 1842, at a cost of 8,575,000 dollars.

The length of this aqueduct is 40½ miles, 33 of which are built of stone, brick, and cement, arched below and above, having a capacity for discharging at least 65 million gallons per day. It is carried over the Harlem River by pipes laid upon 15 arches, of which seven are 50ft. span, and eight of 80ft. span.

This bridge is 114ft. above low water mark.

At the place where the Croton dam is constructed, the water of the creek was 38ft. lower than the head of water, but by going further up the river a dam of less height would have done, but a certain amount of water supply area would have been lost. The flow of water at the dam averages much about the same as our River Lea, say 50 to 60 million gallons a day; but the minimum is 27 million gallons. The water is held back by the creek dam for about six miles, forming in itself a large reservoir of at least 400 acres, known as Croton Lake. The capacity of this reservoir, down to a point where the water would cease to flow into the aqueduct below, is about 600 million gallons, independent of the receiving reservoirs in the city then built, capable of containing 150 million gallons more when full, which together afforded a reserve supply of 750 gallons for seasons of extreme drought. Besides all this, in case of great necessity, other streams can be readily turned into the Croton river above the reservoirs or direct into the aqueduct. So that you see the Americans, as far back as 1842, provided a far better supply to their city than we have at the present moment to the largest city in the world; and these Americans have not been slow to keep up their water supply proportionally to the growth of their capital, which now exceeds 190,000,000 gallons per day.

Spring and Well Water of England delivered in Calais.

This appears curious, but why should it not be, considering that the bottom of the Channel is formed upon the following: First there is a layer of chalk marl impervious to water, then one of greensand, porous and capable of saturation, and then an underlying layer of impervious clay. The under clay runs from Kent and Sussex beneath the Channel to Calais, the water in the Calais wells coming from rain which fell on the hills of the south of England.

East London Water Supply and Local Board Inquiry at Hackney Royal Commission.

(*From October 1st to the 5th, inclusive,* 1895.)

In the first place we will speak of the East London Water Works Company, and take these people as an illustration of one case, which has brought about an unnecessary amount of downright twaddle, and, I say, an alarming amount of unnecessary ill-feeling through misrepresentations.

I have said that a constant supply required for the East London Water Works Company must be provided with proper storage.

By examining other parts of this work you will see that the East London Water Works Company depends greatly upon the River Lea for its supply. That the River Lea greatly fluctuates. That in times of storms it is apt to, should the land be saturated with water, which, by-the-bye, has not been the case all this spring and summer (for I have had this from Mr. Corble, who represented the Lea Conservancy Board during the Hackney Royal Commission on the Water Inquiry) become flooded, and this is the very worst time for taking water into storage reservoirs on account of the amount of both animal and vegetable substance brought down with the streams. (See tables.)

Now, this being so, and the increase of population and the extraordinary amount of waste of water which is taking place, together with the drought of the early part of the season, this Company had an insufficient amount of storage or reservoirs. The consequence is this—that they were compelled to reduce their supply to a matter of two to three hours per day for a week or so.

The consequence has been this—that the house-owners, to save expense, have thoroughly ignored cisterns, under the plea that they are insanitary. The consequence is that these poor people had not any means of providing themselves with the necessary supply. But the matter does not rest here, there being an undercurrent at work.

Nearly everybody seems, through ignorance, to be against the Company, because they were powerless to grapple with the enormous waste and shortness of water from the Lea. In fact, nearly the whole of the East London people attributed this shortness of water to leaky mains, and stubbornness or mismanagement of their work

and Mr. Bryan, their engineer, I must say, has been most unmercifully ill-used for that which he had not the slightest control over. Why? Simply because three or four years ago he saw what was coming, and the necessity to increase the storage capacity of their reservoirs. And the Company applied in 1893 and 1894 to Parliament for grants of money, and a Bill to empower them to do so. This Bill was opposed by the London County Council and Co. They definitely refused to sanction the raising of capital for the new storage and pumping works, which, had the Bill passed, the new reservoirs would have been available by the time the scarcity occurred, to the extent of 200 million gallons, and a new pumping apparatus for pumping three million gallons daily; so that you see if the Bill had not been rejected there would have been no deficiency. And more than this, had the house-owners not have done away with their cisterns, or built houses without cisterns, even though the water was scarce, I verily believe that there would have been no trouble

Some may turn round and say (which, unfortunately for the consumers, they have), "But cisterns are insanitary, and not necessary under the constant supply." Then, I say, they know nothing of what they are talking about; for it is impossible to always have water in your house if you have no cistern. For the time of repairs, additions and breakages must come, and during this period where are you?—for the time exactly in the position that the East Londoners have been.

Then can it be said that you can make sure of a constant supply without cisterns?

Cisterns, from a sanitary point of view, have been made and patented over and over again for at least this last 25 years, thus doing away with the first portion of the argument. There are close tanks, with pipes coming direct off the mains, with or without ball-cocks (what we call high-pressure tanks), provided with a proper floating ball, round rubber, or other air-valve in their top, which tanks may be fixed below ground, or above, or in any out-of-the-way place, and may be had to suitable dimensions, see Fig. 1,083.

There are other tanks known as the Water Egg, which will stand alarming pressures, and serves the same purpose; yet we are told that these tanks are insanitary by those who were against the Company. But the Company happened to have quite as reliable witnesses. For instance—Dr. Dudfield, Vice-President of the Society of Medical Officers of Health, and Medical Officer to Kensington, who could see no objection to the use of cisterns if *properly kept*. And he recommended their use, and was surprised at their being abolished anywhere. There were many other such witnesses present ready to confirm the assertion.

Of course, cisterns, like everything else, require to be looked after, and in places where they will not look after these cisterns, then put the ordinary round, closed-up, circulating tanks in their stead. There is no patent to be feared, and, as before said, such have been in use for many years past, and I know of no place where they have not given great satisfaction. As to the closet supply, during the time the water may be cut off for a few hours let the people throw their dirty water down, and there cannot be any harm for a few hours should the water happen to be turned off through unavoidable circumstances, which is bound to occur occasionally, and those who are too lazy to do this are not of much worth to the living.

The Shattered Mains Bubble Inquiry.

There was a great deal said by the engineer for the London County Council and others about the, as he chose to term them, shattered mains of the East London Water Works Company, which goes in my mind to prove that there was something in the background of this affair; for he distinctly said that with these pipes or mains something of an exceptional character occurred, meaning the great loss of water thereby up to at least the end of June; whilst the chief engineer, Mr. Bryan, distinctly said, through his counsel, Mr. Pember, Q.C., that the whole of their mains were repaired in London *by the 8th of April*, and in the country districts *by the 19th of April*, which could be proved by vouchers for opening the ground placed in the hands of the vestries. In fact, Mr. Bryan ridiculed the idea of shattered mains, which he substantiated by the voucher proofs, and attributed the entire shortness of water for June, July, and August to the drought in the Lea Valley, which for the first six months was unprecedented in his 14 years' experience. The rainfall for the first six months and a half being only 5in., and up to May 26th all the reservoirs were full and overflowing, but from that time (*when the pipes were all repaired*), they *fell rapidly day by day until the 28th of June*, when they were compelled to cut off at night for an average period of nine hours for over two-thirds of the Company's area. The other third was not cut off because of the fire mains. The flow of the Lea began to decrease on the 26th of May, when it was ten million gallons less on the previous day; on the 26th it was 43,209,000 gallons. During the month of June the daily average flow was only 24,300,000 gallons, of which the Lea Conservancy was entitled to take 5,400,000 gallons. After June 28th the flow was further decreased to 22 million gallons daily. On July 15th the service to the consumers was reduced to three hours a day, the reservoirs being practically empty. The service of three hours per day lasted till 28th of July, or just a fortnight. It was then increased to six hours a day, and stand pipes were erected. On August 16th it was further increased to eleven hours per day, and evidently made constant again on the 8th of September.

There was no truth that a short service was given in any case.

Posters were put up, asking consumers to economise their water as much as possible, together with 170,000 handbill notices, and advertisements in the district papers.

The amount of water pumped per head for each day was as follows:—

The week ending July 5th, 40 gallons; July 12th, 39 gallons; July 19th, 33 gallons; July 26th, 29 gallons (the minimum reached); August 2nd, 32 gallons; August 9th, 32 gallons; August 16th, 33 gallons; August 23rd, 36 gallons; August 30th, 36 gallons.

He, the engineer, emphatically denied that the loss of water was through shattered mains, and attributed the scarcity to the failure of the River Lea, due to drought, and being barred by not having the necessary Parliamentary grant sought for, which was opposed by the London County Council, for making the necessary storage reservoirs and machinery, which would have enabled them to have tided over what he had foreseen, the shortness of water, years past.

Mr. Bryan was severely cross-examined by Mr. Balfour Brown, Q.C., for the public, and Mr. Freeman for the London County Council, and also by those appearing on behalf of the different vestries, but which evidence could not be shaken.

Quantity of Water used by each Person Daily.

The following is my experience: That what is sufficient for one house is totally inadequate for another. I will number these as one, two, three.

Firstly—Take what is called a first-class house; say of seven in family and two servants.

Such consumers, when on the constant system, use much more water than when the intermittent supply is given, as follows:—

The master in the morning must have his bath. Here goes thirty gallons. Say that only four out of the seven take one bath per day. Here to begin with is 120 gallons, which in the summer is often doubled.

The closets, on the average, are used, in and throughout the house, twice a day, and the handle is pulled generally before and after use, which represents, to say the least, eight gallons for the four people each, or another eight gallons.

Should there be a spray bath, which is now becoming general in large houses, the amount of water used will be double for bath purposes.

Cooking and for culinary purposes, at least, on the average, three gallons is required for each person, making another twelve gallons.

Water for bed room purposes, average one gallon each person. Water for washing floors, or scrubbing purposes, average the minimum quantity two gallons per day for each person, which brings us up to 176 gallons for the four people, which in the summer time, when evening baths are required, brings us up to 296 gallons, which, divided by four, you have 74 gallons to each person, to say nothing about waste, garden supplies, &c.

These are items which have come under my personal notice many years past, and at the present time.

The Poorer Class of Houses.

First of all is the body washing, requiring three gallons for each person per day.

Closets—eight gallons.

Dietetic purposes—two gallons.

Linen washing—four gallons.

House scrubbing and odd work—one gallon.

This is the least they can do with to keep themselves clean.

Here it amounts to 18 gallons per each person.

This I have tested by metre in Ely Place, Kingsland, so far back as 1873; also at the Model Lodging Houses, Mint Street, Borough, so late as 1880, and in many places since.

The waste, if only a ½in. pipe, let to run full bore one hour will use up 400 gallons, and has amounted to as much as 4,000 gallons in one single night, leaving a tap running for a matter of ten hours at a time. There is a prevalent idea mongst certain people that if a drain should happen to ink that it requires flushing, and these people think hing of setting their taps to run full bore for hours and s, yes, and nights upon nights together, whilst, in ity, such stinks are pouring from the sewer into their mises for the want of proper trapping, &c.

nother extraordinary amount of waste takes place ring frosty weather by people leaving their taps to run ght and day for weeks together, they knowing that when ater runs through the pipes the water from the street ains will be of sufficient temperature to prevent their ipes from freezing, and I have consulted the water works people of my neighbourhood, and other places, as to what they think would be their loss of water from this particular cause, and I am assured that it has amounted to, at least, fully half of the ordinary supply.

The middle class houses can be very well taken on the average as coming between the two. This I have tested over and over again, without having the slightest regard for feeling between the consumer and the water works people, nor have I the faintest interest on behalf of either, excepting in the interests of justice, for, although I have spoken up as anyone should do when the facts are brought to light, it should be known that I am *my own water provider*, and, therefore, quite independent and disinterested with anything connected directly or indirectly with the water companies, their fittings, shares, or people connected therewith, or their consumers.

Garden Water Supplies and Waste.

The amount of waste which goes on in times of drought for what is known as garden supplies is beyond conception. The water is usually laid on in good faith that the consumer will use it judiciously, and according to about the size of the garden and glass houses, so the amount of water rate is charged. But after everything has quieted down and all forgotten, excepting the collection of rates, you may go to the back part of some of the houses, and I could mention dozens about this particular neighbourhood who have, since the putting on, introduced the lawn sprinkler, Figs. 932 and 933, also small fountains, which latter are allowed to run week in and week out during the summer time. Now refer to the lawn sprinkler, Fig. 932.

This will only play out over a certain area when the ½in. pipe is full on.

The fountain plays for a quarter of an hour in each place, often a much longer time, especially if forgotten, and say on a good sized lawn it requires ten shifts. Here is 1,000 gallons or more per day. Say it is used three days a week. This will equal 3,000 gallons. Say one out of ten houses has such apparatus. Here is 300 gallons to be added to the consumer's quantity, and this is one of the places out of dozens besides, which in times of drought plays an important part in the shortness of the water supply.

Builders' and Painters' Water Supply.

It is not generally known that this amounts in one year to at least 100 gallons per house of seven rooms, and so on in proportion to the size of the house.

As a rule most of this water is taken in the dry season, and as we have at least 600,000 houses, it means a nice little drop, which is scarcely ever thought about.

London Water Supply and the Details of the Welsh Scheme.

415,000,000 GALLONS IS SAID TO BE PROCURABLE PER DAY.

The London County Council has authorised its Water Committee to expend £2,500 in making surveys and obtaining other information with respect to the scheme for obtaining a water supply from Wales. In the first place the Committee visited the site of the proposed Llangorse reservoir. The supply to that reservoir would be mainly derived from the upper part of the Usk valley by conduits, which would skirt the hills at an altitude that would leave the lower and more populous portions of the valley entirely untouched. The water from those upland drainage areas, 121,000 acres in extent, including the district of the Black Mountains lying eastward of the town of Brecon, would be led by conduits for the supply of London into a large reservoir, which could be economically formed on the site of an existing shallow lake called Llangorse. The top water level of the lake, after being raised 93ft., would be 595ft. above the sea, and its area would be increased from about 358 to 2,800 acres, being five miles long by one mile and a half broad. The contents would be about 38,000 million gallons, and the dam to retain that enormous quantity of water would be only 130ft. in height as an extreme, and of comparative short length. Of the purity of the water that would fill this reservoir, the Committee speak in high terms. The construction of this reservoir would involve the diversion of a portion of the Mid-Wales and Brecon and Merthyr Railways near their junction at Talyllyn; but that diversion could be easily effected, with advantage to the railways. After making deductions for dry years, evaporation, and compensation, a supply of 182,000,000 gallons a day could, it is said, be obtained from that source. "From this reservoir," the Committee say, "the main aqueduct would commence and carry water to London,

being joined at a distance of about seven miles from Llangorse by the tributaries which would flow in from the northward." They point out that each of the proposed reservoirs would contain 180 days' storage. Next was visited the reservoir in the Towy valley district, from which water could be conducted by means of a tunnel 4½ miles long, into a reservoir proposed to be constructed at the river Yrfon, about a mile above the village of Llanynis. It was at this point that the second great branch of the scheme would be located. There was an available drainage area of some 67,000 acres running up to altitudes of from 1,700ft. to 2,000ft. above the sea. A dam across the river 166ft. in extreme height would form a lake 2,850 acres in area, the top water of which would be 606ft. above the sea level, and would contain 31,000 million gallons. That lake would form, with the island which it would contain, a most picturesque object in the landscape, it having a serpentine course of over six miles in length, with three branches to the northward from three-quarters to one mile and a half in length. In this case also a diversion of the Central Wales Railway would be required. In addition to the natural drainage area of the river Yrfon, the drainage from 19,800 acres of the Upper Towy could be poured into the Yrfon reservoir by diverting the flow of the River Towy as already mentioned. From those two areas on the Towy and the Yrfon a supply of 135 million gallons a day was available for London, after making liberal allowances for dry years, compensation to the River Yrfon, and the proper proportion of evaporation. In the valley of the Edw, a tributary of the Wye—(how about the people living on the banks of this WYE River, say Hereford, which is very short of water now in the summer time?)—there was an available drainage area of 17,000 acres, situated above an admirable site for a reservoir of 570 acres in extent, the top water of which would be 700ft. above sea level. The drainage area was composed of rocks of the upper and lower silurian series, with certain interpolated volcanic beds, and would give a supply, after dry years, evaporation and compensation had been allowed for, of 18 million gallons a day. At a point about four miles above Rhayader there was a remarkably good site of about 22,000 acres, the whole of which is composed of the lower silurian beds of the Llandovery series. It ran up to great altitudes of over 2,300ft. on the slopes of Plynlimmon. A reservoir having an area of 900 acres could be constructed. Its extreme length would be 4½ miles, with an extreme breadth of about half a mile. The dam would be about 130ft. in height, and the capacity of the reservoir 10,500 million gallons. From that reservoir, after providing for dry years, evaporation and compensation, a supply of about 43 million gallons a day could be obtained for London. The last inspection was that of the Ithon Valley. At a point about a mile above the village of Ystradenny, there was an available drainage area of 25,000 acres, running up to altitudes of from 1,200 to 1,500ft. above the sea. A reservoir could be constructed of about 900 acres in extent, which would contain about 9,000 million gallons, and give a supply of 37 million gallons daily for London. From the sources indicated, a total of 415 million gallons a day could be obtained. Thus, in the opinion of the Committee, the scheme appears to afford the prospect of a pure and plentiful supply. On the question of purity, however, they propose to take further evidence. Meanwhile they are employing several engineers on the surveys, and they promise the Council further information at the earliest possible opportunity. The Committee submit no recommendations, but in conclusion they say that "One of the advantages of the scheme is that it may be carried out by instalments, and that, assuming the present sources of supply to be maintained, a supplementary supply of purer and more wholesome water may be obtained from Wales sufficient for the requirements of London forty years hence, at a cost little, if at all, exceeding that which would be incurred by the formation of reservoirs in the Thames Valley."

Another paragraph in the same Committee's report will ask the Council to sanction an expenditure of £35 that has been incurred in connection with microscopical examinations of the finer suspended matters in London water, these examinations having been undertaken "so as to differentiate as far as possible the various smaller organisms, especially the bacteria."

The Parliamentary Committee will submit a report with reference to the Water (Transfer) Bills, which, on the 9th July, 1895, in view of the dissolution of Parliament, the Council decided to suspend until next session. The Committee submit the following recommendation:—"That, desiring that the supply of water in the metropolis and the surrounding districts should be in the hands of a public authority, and with a view to a complete agreement with all parties concerned over the entire area supplied, the council do invite H.M. Government either to deal with the question themselves or to appoint a Royal Commission to do so."—Mr. Stuart, M.P., has given notice that he will move, and that Mr. McKinnon Wood (Chairman of the Committee) will second, this amendment:—"That the Bills for the purchase of the London Water Companies be proceeded with."

A recommendation was submitted by the Parliamentary Committee, in reference to the eight Water Bills promoted by the Council in the last Session of Parliament, that the Council invite the Government either to deal with the question of water supply themselves or to appoint a Royal Commission. Mr. Stuart, M.P., moved as an amendment that the Bills for the purchase of the undertakings of the London water companies be proceeded with. After a debate, in the course of which Lord Farrer opposed the amendment, it was rejected by 54 to 53 votes. The debate was then adjourned.

WATER ANALYSING.

RAIN WATER (SYMBOL H_2O).

Owing to the solvent power of water, it is never met with in a state of purity, though unquestionably rain water is nearer this state than any other. This class of water is generally mixed with atmospheric air, to the extent of about 2½ per cent. There are various methods of getting the air out of water, but the one I prefer is by boiling in a retort luted to a pneumatic apparatus, which may readily be understood by reference to J. J. Griffin's Catalogue, or to almost any work on Chemistry. Try Roscoe's or Bloxam's "Elementary Chemistry."

Should you suspect the presence of any of the following in your water, and have no chemical tools to work with, the following methods will be useful and most interesting in your spare evenings.

CARBONIC ACID.

Carbonic acid not combined with a base, or combined in excess, can be discovered as follows. 1. Lime water occasions a precipitate soluble with effervescence in hydrochloric acid. 2. The infusion of litmus is reddened, but the red colo- disappears, and can be restored by adding

more of the mineral water. 3. When boiled it loses the property of reddening the infusion of litmus.

Mineral acids, if present uncombined in water, give an infusion of litmus a permanent red, no matter if the water has been boiled.

SULPHURETTED HYDROGEN.

Section 1.

Water containing this can be distinguished with the following. 1. By its peculiar odour. 2. It reddens litmus fugaciously. It blackens lead test paper, and precipitates nitrate of silver, brown or black.

ALKALIES AND AMMONIA.

Alkaline and earthy carbonates may be distinguished as follows. 1. By an infusion of turmeric, or with turmeric test paper, which is rendered brown or a reddish brown according to the quantity. 2. Paper stained with Brazil wood, or an infusion of this, will be rendered blue; but note that this is also produced by alkaline and earthy carbonates. 3. Litmus paper reddened by vinegar is restored to its original colour. 4. If these changes be fugacious with the alkali, look out for ammonia, which you can easily discover with the Nessler test for ammonia (though exceedingly delicate), which any good chemist will make for you.

ALKALIES (FIXED).

These exist in water, and occasion a precipitate with muriate or chloride after being boiled. Volatile alkali can be distinguished by the smell. It can also be seen with the above test if you distil a portion of the water.

METALLIC AND EARTHY CARBONATES.

These may be observed by precipitation by boiling the water, except the carbonate of magnesia, which can only be precipitated imperfectly.

IRON.

This can be discovered by tincture of nutgalls, which gives water containing iron a purple or black colour. If the tincture has no effect upon the water after boiling (though it colours it before) the iron is in a state of carbonate.

The following are useful hints. 1. A violet indicates an alkaline carbonate or earthy salt. Dark purple indicates other alkaline salts. Purplish indicates sulphuretted hydrogen gas. Whitish and then black indicates sulphate of lime. 2. The potassium ferrocyanide will occasion a kind of blue precipitate in the water containing iron. If an alkali be present, the blue precipitate does not appear unless the alkali is saturated with an acid.

Poisonous Metals.

There are various kinds of poisonous metals which at times contaminate our water, but I shall only treat upon the six most common, namely, iron, lead, zinc, copper, arsenic and barium, and shall lay particular stress upon lead, as it forms an important item in this analysis of water, and no analysis of drinking water is perfect without looking for this particular metal. Lead undergoes no alteration in a dry atmosphere, nor even when sealed up in a vessel of *pure* water, especially if the water had been previously boiled to expel all air, and under such cases the metal will retain its brilliancy for an indefinite period; but if exposed to the united action of air and pure water it will be quickly subject to a powerful corrosion, and become oxydized at the surface, and thus an oxide of lead is formed, which is readily dissolved by the water; this solution readily absorbs carbonic acid, a film of hydrated oxycarbonate of lead ($PbO, HO + PbO, CO^2$) is deposited in silky scales; then a fresh portion of oxide is formed, which again is dissolved by the water, and so it, the water, becomes poisoned. But you must be particular to notice the circumstances which has produced this, namely, that of *pure* water.

There are various kinds of salts such as sulphates, phosphates, and carbonates in water, which modifies all this, yet others, such as chlorides and nitrates, will increase the rapidity of the corrosion.

An oxide of lead is scarcely soluble in water which contain sulphates, the phosphates, and the carbonates.

Bicarbonate of lime is remarkable for the preservative influence which it exerts on lead, thus spring waters very rarely act upon the metal to any dangerous extent, and hence one reason why I have recommended a good coat of hot lime wash to be put on all leaden cisterns, used for the storage of water for drinking purposes, which forms a film of insoluble carbonate of lead upon the surface which protects the metal beneath from further injury.

Perhaps some of my brethren may object to smarming their work over with lime wash. Let that be how it may, it is of great importance in its sanitary bearings, and such being the case, whether it offends the eye or not, it should be done.

Rain water is at times collected for household purposes, and great care must be observed to ascertain whether this water is sufficiently impure to prevent action upon the lead, if such be used for the cisterns, which may be ascertained by adding a drop of colourless sulphide of ammonium to a portion of the water taken from the cistern after a few days' standing, the longer the better. The water should be held in a small cylinder standing upon a white surface; should there be any lead the water will darken, if not it will remain unaffected; and it would be quite as well to have two cylinders, one to contain water with the test, the other to contain the sample without the test. If very minute portions of lead are there, slowly evaporate the water to about a hundredth part, when your test will be one hundred times more powerful.

Another way of testing whether there be any action of rain water on lead is, by cleaning two strips of the metal with a shave hook, and leave one perfectly clean, the other allow to tarnish of itself; place the two in two beakers of water, and leave them to stand for a week or so; then take a flask (a child's feeding bottle will answer), and put two or three little bits of *sulphide* of iron therein, and a solution of six of water and one of concentrated sulphuric acid, which will generate sulphuretted hydrogen gas. Now with a small tube perfectly clean (a small tube of glass on to the end of the rubber of the feeding bottle, the bottle should be corked and the only outlet at the tube), convey a few bubbles of the sulphuretted hydrogen gas into the bottom of the beakers containing the water, *after the metallic lead is withdrawn*, and notice the difference in the colour of the liquids. If there be none, get a third beaker of the rain water before it has passed into the cistern, and compare the three. Should there be no difference, test all the waters with a colourless sulphide of ammonium, and also with a solution of coloured sulphide of ammonium. If you can find no change you may almost rely that there be no lead present; but if you should discover traces of lead you must confirm it, and also get the amount, which is done by dropping two or three drops of acetic acid into about a hundred cubic centimetres of water, and about five cubic centimetres of the solution of the before-mentioned sulphuretted hydrogen. You will here discover a tint, which can be compared by forming an artificial sample made by adding a known quantity of solution of salts of lead to one hundred cubic centimetres of distilled water.

Dissolve 0·831 gram of crystallised normal sugar of lead in a litre of pure water. This will produce a solution containing 0·0001 gram of metallic lead in 100,000 parts of water, which we now call the standard solution, and which, if divided by the simplest form of 10, the number of cubic centimetres needed to produce the exact colour, or tint; as the sample for comparison of the pure water.

There are some salts of lead which are scarcely soluble in pure water, namely, the hydrated oxycarbonate of lead; this will only take up in pure water one part in four millions, or about one sixtieth of a grain per gallon.

Oxide of lead in solution and in solution of distilled water, say four or five grains to the gallon, becomes filled with silky crystals of the hydrated oxycarbonate when exposed to the air, owing to the absorption of carbonic acid, and in a few hours the water will not contain the metal in solution to a greater extent than one four millionth part.

Water, if highly charged with carbonic acid, may, nevertheless, dissolve lead to a dangerous extent, owing to the solubility of the carbonate of lead in excess of carbonic acid; but when water is thus impregnated with the lead and is boiled, the gas is expelled and the carbonate subsides.

Lead is rapidly corroded when in contact with wet sulphate of lime, so that it should not be brought in contact with damp stucco or plaster; in fact, so bad was a case of this kind, that the whole of the lead paraffin tanks at the Atlantic Wharf, Bow Common, many of which are seventy to eighty feet long, twenty to thirty feet wide, and from eighteen to twenty feet deep, I had to reline after they had been down only about ten years. The firm who originally lined them had secured with iron nails the sides and ends to a wooden wedge driven into the compo, and covered the heads with a patch burnt all round. The consequence was this, that the tanks, being underground without any means of ventilation, commenced sweating between the lead and the stucco wall, where there was every chance for chlorides and nitrites, owing to the fact that this was the site of an old chemical works, the old bricks of which were full of such chemicals, which bricks were ground in a mortar mill and used for the stucco. Then there were the iron nails, which at once would account for the corrosion, which was extremely bad for half-an-inch to one inch all round. Why? Simply because the moisture through the sweating, the iron, and the lead, there was a splendid couplet set up, and the wonder to me is that the tanks lasted so long as they did. Anyone wishing to see the effect of such work are welcome to examine some of the specimens which I have here, by writing me for an appointment. This was a job of about £6,000 through the plumber's want of knowledge of the circumstances connected with the trade.

Iron and Lead.

Now we are on the point of the corrosion of lead, it will be well to draw your attention to isolated cases of lead water tank leakage, which seems to have puzzled a number of people who have seen this corrosion, and who, though chemists, have been unable to trace the cause; and as an example of such I deem it proper to record the following which is taken from the pages of the Science Gossip Club, instituted 1870. The Annual Meeting which was held at the Royal Hotel, Norwich, May 22nd, 1889. *President*, Mr. John Bidgood, B.Sc., F.L.S.: *Vice-Presidents*, Mr. J. B. Bridgman, F.L.S., F.E.S., Mr. T. S. Breese, Mr. F. H. Ellingham, Mr. A. W. Preston, F.R. Met. Soc., Mr. T. J. Dixon, Mr. S. W. Utting: *Treasurer*, Mr. Edward Corder: *Honorary Secretary*, Mr. W. A. Nicholson, 112, Trinity Street, Norwich: *Committee*, Mr. Fred. Heath, Mr. A. E. Col, Mr. Thomas Allen, Mr. J. De Carle Smith, Jun., Mr. G. Christopher Davies, Mr. J. H. Stacy, M.R.C.S.: *Journal Committee*, The President, The Secretary, Mr. Thomas S. Breese, Mr. James Carver, Mr. F. H. Ellingham, Mr. S. W. Utting.

There are about 100 members, of which a large number were present.

After talking about what they had done during the year at different monthly meetings on biological, physical, mathematical and astronomical, geological, chemical, meteorological, and literary subjects, to say nothing of little odds and ends, such as the Correlation of Structure with Function, as Illustrated by a Dead Nettle; A Chapter on Evolution, by Mr. J. Bidgood; Setting of the Clock, Having Regard to the Uniform Standard of Measuring Time, by the Reverend J. Preston, M.A.

Phosphorescence of Animals, Showing the Striking Phenomenon as the Emission of Light by Animal Organism, by Mr. T. Irwin Dixon.

Motion, after Showing How the Friction of those parts of bones which play upon each other was lessened by means of a cover of smooth cartilage, lubricated with a viscid albuminous substance called Synovia, by Mr. Donald De Day, M.B., F.R.C.S.

Jesuits Bark, by Mr. Edward Corder.

Sleep and Dreams, which was a very interesting paper, by Doctor Barton.

The Microscopical Evening. The president read a paper on The Reproductive Organs of Snails. The Gizzards of a Cricket and Cockroach, which was a most digestive paper, by J. B. Bridgman, F.L.S.

Mr. Edward Corder, on the Bell Animalculæ; followed up by Antennæ and Tongues of Insects, by Mr. T. J. Dixon.

Mr. H. A. King, chemist, of 88, Exchange Street, Norwich, showed a section of Coal from Newcastle, containing glandular cells; also Fern Spores, taken from Coal, and a specimen of Fossil Wood from California, showing the coniferous structure of the wood. He also described and exhibited a section of a Meteorite, containing fluid cavities.

Reproduction of an Eel, by Mr. Thomas Southwell, F.Z.S.

Human Blood Crystals, by J. H. Stacy, M.R.C.S.

The Propulsion of Vessels by Wind, from a Scientific Point of View, also Describing the Principles of Floatation, by Mr. G. Christopher Davies.

Chara, by W. A. Nicholson.

Wellsbach Gas Burner and Regulators, used in Gas Works, by Mr. R. A. Pank; and a quantity of other scientific subjects, such as Electricity, Lantern Microscopic Work, Notes on a Thunderstorm, &c., &c.

These illustrations are only to show that there are men of talent connected with this institution, yet when it came to the subject of lead and water pipes, they were somewhat as I have seen hundreds before, puzzled, though Mr. King grappled with this subject better than any chemist or metallurgist that I have seen or heard of.

After a quantity of letters passing between us upon the following subjects, Mr. King is described on page 15 of their annual report, as follows:—

"Mr. H. A. King, in describing his investigation into the cause of a peculiar corrosion of some lead water pipe, exhibited by Mr. Bridgman at an earlier meeting, stated —'That the lead pipe in question had been used for conveying Norwich Water Works water for about twenty years, at the end of which time portions (several inches in length) were found riddled with minute holes of $\frac{1}{20}$th to $\frac{1}{8}$th of an inch in diameter, the peculiarity being that the holes commenced from the inside of the pipe, and in most cases had burst through the wall, the internal pressure (presumably of the water in the pipe, about 50lbs. to the square inch in Heigham, where it was laid) having first caused the thin wall to project outwards, forming little prominences visible on the outer surface.

"'It was evidently *pressed pipe*, and the walls were

much thinner than those of pipes allowed to be laid now, being only ⅛th of an inch thick for a pipe of ¾in bore. Had it been used for conveying sewage matter there would have been no difficulty in finding a cause for the holes, but as it had been used for Norwich Water Works water only the cause was more obscure, and must obviously lie in some impurity introduced into the pipe, either in its manufacture or by accident afterwards.

"'In order to present to the meeting a probable solution of the question, Mr. King explained the manufacture of lead from its ores (and exhibited specimens), drawing attention to the stages in the process at which impurities might enter.

"'The various processes of manufacture of lead pipe were next explained in detail, specimens being shown, and it was pointed out that in *pressed pipes*, in which the steel *core* was used to regulate the bore, a possible impurity would be caused by minute spicules, or iron, adhering to the core and becoming embedded in the inner surface of the molten lead as it was forced through the press.

"'Passing on to the use of the pipe, attention was drawn to the fact that, in connecting lead service pipe with iron mains, a brass ferrule was often attached to a hole in the main, and to this the lead pipe was soldered. This was done to separate the iron and the lead, and thus prevent the well-known galvanic action that would occur in the presence of air and moisture, if they were in direct contact. But here occurs another possibility. In drilling the iron mains minute particles of iron might' (they do, and hundreds of thousands of them) 'fall into them, and after the connection with the service pipe was made these particles might be driven by the force of the water into the lead pipe, and being sharp and hard might catch in the lead and set up the action it was intended to avoid. This action of iron in causing the corrosion of lead may be well observed in the case of iron nails exposed to the action of air and moisture in lead roofs and cisterns. Specimens of lead and iron nails from tanks and cisterns in which this action had extensively occurred were shown, kindly contributed by Mr. P. J. Davies, M.S.A. (of London). In the case of our lead pipe the holes were nearly all filled with a reddish-yellow substance, easily powdered, and found on analysis to consist of salts of lead, together with traces of iron in every hole, no iron being found in any other portion of the pipe, iron thus being suggested as the source of mischief.

"'As the text books on chemistry throw very little light on the subject, and as several practical plumbers who were consulted were unable to give any explanation' [I may here remark that an advertisement appeared in one or two of the leading building and chemical trade journals offering a substantial reward to any one giving a satisfactory solution to this question, which was only answered by myself. I being the only one to reply would not take the reward, as of all my writings for trade journals and otherwise I would not, upon any consideration, do it for money, nor shall I by any way ever be repaid half the money which this work has cost to produce, it being a work of love to benefit my fellow-workmen, as up to the present moment I have spent over £7,000 in experiments, travelling, searching, engravings, printing, and such like on the work], 'experiments were performed to try and determine how far minute particles of iron in contact with lead under water, charged with air and carbonic acid gas, would effect the oxidation of the lead, the difficulty being to understand how iron, which is slightly electro-positive to lead, should cause the oxidation of lead, especially after metallic contact is destroyed by the formation of a layer of oxide of iron between the two metals, unless by galvanic action the iron was first oxidised and the lead was afterwards oxidised by the oxide of iron formed. As a matter of fact, it was found that if lead in which small particles of iron were imbedded was exposed to air and moisture for a few weeks, the surface of the lead in the neighbourhood of the iron became coated with oxide of lead as well as oxide of iron. In one experiment a nail was loosely fixed in a piece of lead pipe and allowed to remain in water for three weeks, after which the nail was removed and the lead returned to the water. At the end of another month the hole made by the nail was nearly filled with a pasty reddish yellow mass, which, on being carefully removed and dissolved in acetic acid, gave to a suitable test evidence of the presence of lead in considerable quantity, and this lead pipe was only attacked just where the oxide of iron from the nail had first accumulated. In another case two pieces of lead were placed in separate lots of water, one piece with a few points of iron nail attached and the other without. After a few weeks the water was tested, and the quantity of lead found in the water containing the combination of iron and lead was much greater than in that containing the lead alone. This seems to show that there is a possibility of an hydrated oxide of iron being formed, leading to the oxidation of the lead with which it may be in contact (in presence of moist air, or immersed in water containing dissolved air), the lead absorbing oxygen from the oxide of iron which, in its turn, reabsorbs oxygen from the air, and if minute particles of iron were introduced into our lead pipe this action may have produced the holes, the cause of which is in question, more especiallly if the pipe was not constantly full of water.

"'As bearing on the *fact* of the capability of iron to produce this effect, letters were read from Mr. P. J. Davies, M.S.A., and author of a standard work on plumbing, in which it was stated from Mr. Davies's own experience that particles of iron, so minute as to escape detection by ordinary means were often discovered in the operation of *lead burning*.' [I should here remark that often the lead burner meets with these impurities, especially in upright burning, which causes him to lose a "drop or bead." He sees a bright something, and very nearly always takes it to be a bit of dirt, which, if it does not fly off, he digs it out with the point of the shavehook. If a man is a good, careful lead burner, you can tell when he meets such by a little irregularity of the burning, but not by the work from an inferior workman's seam.] 'That he had known them to cause the destruction of lead if exposed to moist air (small as they were). He also stated that when oxide of iron was formed on lead, oxidation of the lead continued as long as moist air was present, even though the iron which set up the action were removed. Amongst other things, in connection with destruction of lead, it was mentioned (on the authority of Kirby and Spence's *Entomology*), that the holes with which lead is sometimes riddled, are caused by the larvæ of a Coleopterous insect (*Callidium bajulus*), in the stomach of which lead is often found. It attacks the fir rafters of houses, and has been known, when arrived at the perfect state, in order to effect its escape, to perforate the lead with which the housetop is covered.'"

There are other ways in which atoms of iron substances and also other metals get into lead. One, especially, is as follows: The lead ashes of commerce are collected by the old lead dealers from all sorts of trades. They find their way to the reverberatory furnace, where to make them readily re-melt without much slag, scrap iron is thrown into the furnace, which becomes melted with the lead. The le[illegible] is not quarter puddled or stirred up so that portions of the iron come away with the red hot lead, and are allowed to cool without any attempt to [illegible] the mass so as to bring up the foreign substances. [illegible] is worked [illegible] done. Then these substances [illegible] to the surface of the dipping pot [illegible] when [illegible] to form the pipe [illegible] pipe go to the melting pot of the lead [illegible] they are re-

into a cake of metal and rolled out. And thus it is well fixed, so that mortal eye cannot by any processes discover it unless by the blowpipe or the action of a solvent such as water. Lead pipes are exactly the same, the action taking place where the moisture is. Cast sheet lead is not apt to suffer from these impurities, because, first of all, the lead *must* be thoroughly good to get good sheets. Secondly, the lead is, as a rule, virgin lead. Thirdly, the skilled eye of a lead caster, if a practical plumber (*this is important as lead has been attempted to be cast by lead mill labourers to the great detriment and scandal of the lead itself.*) The skilled plumber sheet lead caster will detect the least bit of foreign substance in his lead pan, and skim it off—in fact, cast sheet lead gets five or six more skimmings than you can ever expect milled to get. Fourthly, in cast sheet lead the lighter substances always fly away before they strike down the sand and into the foot pan, and is twice more skimmed before such lead is used. Lastly, such destruction of lead by iron is not known in cast sheet lead. Plenty of roofs are to be found two or three hundred years old which I would challenge anyone to produce one bit of such metal pocked, as is the case with the milled lead.

One more cause of destruction of lead. Some four or five years ago I was called upon by Messrs. Ratey and Kitt, the well-known church builders of Cambridge, to examine and report upon the cause of the rapid decay of the lead flat covering the roof of Jesus College Chapel, Cambridge, one of the noted best pieces of British architecture in England. I had no intimation that many scientists and architects, plumbers, &c., had been called to examine this important decay. I found the lead work externally as good as new, well laid, and everything appeared all right; but on Mr. Kitt, junior, turning up the ends of one or two of the bays, found the lead in a state of rapid decay, and, looking around, could not find the slightest reason externally. It occurred to me, as passing round the narrow stone galleries inside the chapel, and especially near the roof, that there was a slight smell of sulphur, which I at the time took little notice of, owing to the fact that most of these kind of places, when high or up aloft, are, as a rule, somewhat stuffy. But the upper regions of such holy places should not be infested with the odour of the lower regions, and nothing was left for me but to cudgel what little brain was doled out to me as a plumber—and I must confess that I for once wished myself out of the job. After some little time I again thought of the sulphur smell, and went roaking about through the galleries, which are by no means pleasant places for a scientific pursuit. Still the sulphur smell was stronger and stronger. Then it came to my turn (remember there was only two of us), to examine the thickness of material between the lead and the inside of the roof, which was boarded, the joints of which were some little distance apart. But not the slightest chance of ventilation between the lead and the woodwork, excepting into the chapel, which, as before said, was exceedingly stuffy, for some 20ft. down. In fact, it was badly vented—shall I say ventilation? Here I considered ventilation. A thought struck me at once; but where was the necessary water to come from to produce the chemical action with the gases of the interior? This did not require much reasoning; it was formed as follows:—Right underneath was a large stove heated with coke, with the stove having rarefying gills, which no doubt produced a splendid heat. This rose directly up, carrying with it the heated carbonic and other gases come from the bodies of the people, to say nothing from what came from the stove itself. These gases and heat, rapidly ascending something about 100ft. high, the heat playing on the under surface of the lead against the colder or external atmosphere, rapidly produced condensation to supply the necessary liquid, and the consequence was the *lead work* required to be laid every few years.

The evil being at once remedied by proper ventilation, and keeping the lead a good distance away from the ceiling, and the lead laid upon soft hair felt, there will be no further cause of complaint for many years to come. Yet you see how easy it is to get work done, which is of a first class character, yet, by an oversight of arrangement of what would be called minor points, the work is, as this was, condemned, by those who have to pay for it, as monstrously expensive and inadequate.

Copper.

[*Also see Salts of Copper.*]

Copper may be estimated similarly to that of lead but for the solutions. To give comparisons, use a solution having ·0001 gram of metallic copper to one cubic centimetre. This is made by dissolving ·3929 gram of crystallised sulphate of copper to one litre of pure water.

Zinc.

As a rule this is found as bicarbonate, and floats near or on the surface of the cistern, in a film of carbonate which must be collected and heated on a platinum foil. Notice whether the volatile matter disappears, if so, and a residue is left, it should remain whilst hot yellow; but on cooling, if it be zinc, it will be white, nearly always found in new zinc cisterns, also galvanised ones.

Arsenic.

Symbol As; combining weight 75; density of vapour 150. This is sometimes found in the polluted waters of manufacturing or mining districts; also sometimes in very small quantities in mineral springs. Two compounds of arsenic and oxygen are known: (1) Arsenic trioxide, As_2O_3; (2) Arsenic pentoxide, As_2O_5. One method of ascertaining the presence of arsenic is to pass a current of sulphuretted hydrogen gas into the suspected solution, when, if arsenious acid be present, it will occasion the appearance of a fine yellow colour through the liquid, which will have no action on phosphate of soda. That substance, however, may prevent the colour forming, although arsenious acid be actually contained in the solution; when such is the case a few drops of very dilute pure nitric acid will immediately produce it.

The following is recommended by Doctor Marcet:—To the suspected fluid, previously filtered, add first a little dilute nitric acid, and afterwards nitrate of silver, till it shall cease to produce any precipitate. The muriatic acid being thus removed, whilst the arsenious acid (if any, and in whatever state) remains in the fluid, the addition of ammonia will instantly procure the yellow precipitate in its characteristic form. It is necessary to add that a sufficient quantity of ammonia may be necessary to saturate any excess of nitric acid the solution may contain. Should there be present common salt where the above test is used, the nitric acid will retain the arsenious acid in solution, whilst the chloride of silver will be precipitated, and must be separated by the filter; the addition of ammonia will then determine the decomposition of the nitrate of silver, and nitrate of ammonia, and arsenite of silver will be formed. An excess of ammonia ought to be avoided, but should it inadvertantly be added, it may be neutralised by a fresh portion of nitric acid, cautiously added, which will occasion the reappearance of the arsenite of silver. Both the nitric acid and the ammonia should be much diluted. The characteristic properties of arsenite of silver are as follow:—

Its [illegible] w. If, after being well washed in distill[illegible] uffered to stand in an open vessel, it grad[illegible] a brown colour; but it does not,

like nitrate of silver, become black on continuing the exposure

It is readily soluble in dilute nitric acid; it also dissolves on adding excess of ammonia at the moment of its formation; but after it has been separated and dried, it is no longer sensibly soluble in ammonia. If a small quantity of this precipitate be exposed to the heat of a small spirit lamp on a sheet of lamellated platina, a white smoke arises from it, and metallic silver remains attached to the platinum. The reduction of the silver, in the form of a globule, is still more distinct and striking if a little carbonaceous matter be mixed with the precipitates and the blowpipe applied.

When the yellow precipitate, enclosed in a tube, is exposed to the heat of a lamp, the white smoke condenses on the portion of the tube, in minute octohedral crystals of arsenious acid.

If both the silver and sulphuretted hydrogen concur in indicating the presence of the poisonous arsenic, no reasonable doubt can be entertained respecting it.

For the more recent test you will require an apparatus, when the arsenic will be easily detected by what is known as Marsh's test.

Arsenic and Hydrogen.

Arseniuretted Hydrogen.

(Caution to Lead Burners and Experimentalists.)

Symbol AsH_3, combining weight 78, density 39.

Look out when you get experimenting with arsenic and hydrogen for the above, or the most deadly gas. It is colourless, but possesses a fetid odour of garlic. One small bubble of this pure gas killed its discoverer, Gehlen, by inhalation.

This compound corresponds to phosphuretted hydrogen, and ammonia is formed by decomposing an alloy of arsenic and zinc with sulphuric acid. As the plumber has, more than any other individual in the chemical works, to do with the generation of hydrogen gas from zinc, sulphuric acid, and water, he should be careful never to bring the blow pipe near his face (a habit which many lead burners practise), for the simple reason that the lead burner may by chance get across some zinc containing arsenic, or he may be compelled to use unknown water which may contain traces of arsenic.

Arsenic and Sulphur.

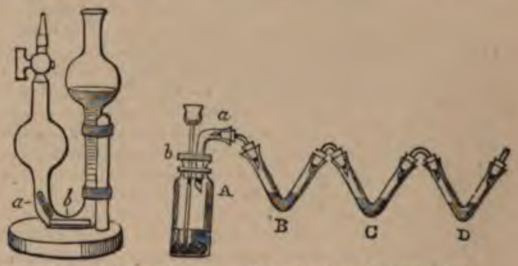
There are three sulphides of arsenic: arsenic disulphide, As_2S_2. This occurs naturally as realgar; trisulphide, As_2S_3, also found in nature as orpiment, and pentasulphide, As_2S_5. Orpiment can be obtained by sending sulphuretted hydrogen gas through the acid solution of the corresponding oxide, when it is precipitated as a yellow powder.

Here the arsenic sulphides form with the sulphides of the alkaline metal compounds having the same analogy to the trisulphides and pentasulphide that arsenites and arsenates do to the trioxide and pentoxide. In point of fact these compounds are nothing more nor less than sulphur salts, the arsenites and arsenates being oxysilts, and this is why they are called *sulph*arsenites and *sulph*arsenates, thus

$$As_2S_3 + 3K_2S = 2K_3AsS_3;$$
$$As_2O_3 + 3K_2O = 2K_3AsO_3.$$

The presence of very minute traces of arsenic can be detected with certainty by solutions precipitated as sulphide, by the aid of sulphuretted hydrogen. This sulphide when dried and fused in a test tube, and with a mixture of potassium cyanide and sodium carbonate, yields a ring of metallic arsenic.

On heating, this metal is oxidised to trioxide, which is deposited in little octahedral crystals. These should be boiled with water, which will then yield a solution, and a bright green precipitate with neutral solutions of copper, or a bright yellow one with neutral silver salts. In fact there are many ways of detecting this poison, such as Berzelius, Fresenius, Regnault, Mitscherlich, Otto, and especially Clark's apparatuses, nearly all of which are supposed to be improvements on Marsh's apparatus. There is one good point about Clark's arsenic apparatus, Fig. 959H, and that is when the arsenic is looked for by Marsh's process, the ingredients invariably contain organic matter, which often causes an excessive frothing during the experiment; but in Professor Clark's apparatus the arsenic separates as follows:—The bottle part for preparing the hydrogen gas is shown at A; the three bent tubes or receivers B, C, D, are connected by small bent tubes of glass through corks. Now we will call the bottle A the hydrogen gas generating machine, the lumps of zinc being shown at the bottom, and the gas is procured by hydrochloric acid not stronger than 12° (= sp. gr. 1·03); in B tube you put a solution of caustic soda; and into C a solution of sugar of lead; and a solution of nitrate of silver into the last, or D.



MARSH'S Arsenic Apparatus. CLARK'S Arsenic Apparatus.

FIG. 959H.

Having the hydrogen gas running through the whole of the tubes for a few minutes, the arsenical liquor must be slowly poured through the funnel into the generator, which allows the frothing to go on vigorously, but without damage, and the arseniuretted hydrogen quietly passes through B, C, D. In B, impurities, such as sulphuretted hydrogen, is deposited. C, is to catch the impurities which B allows to pass. This depends upon whether you have too much generating force in the generator which must work slowly. In D is thrown down metallic silver, and the arsenic remains in the solution.

After the generator has ceased to generate gas the arsenic liquor caught in D is mixed with pure hydrochloric acid, this will throw down all the excess of the silver.

The liquor is then filtered, afterwards it is evaporated to dryness, and the product will be pure arsenious acid, which can be tested by the means I have already described.

Barium.

Evaporate the water down to a minimum and acidulate the same with hydrochloric acid, and, if necessary, filter it and test with a solution of gypsum.

Hardness of Water (Temporarily)

Some water contains a considerable amount of carbon[ate] of lime, $CaCo_3$—, lime stone, &c., which, being dissolv[ed] cannot be removed by the process of filtration. But m[...]

be to a considerable extent by boiling, when it deposits a crust of calcium carbonate, owing to the escape of the carbonic acid. This crustation, found on the sides of boilers, may be avoided by adding to the water a small portion of sal-ammoniac, soluble calcium chloride, and volatile ammonium carbonate being formed.

Hard water, with dissolved carbonate, can be softened by adding lime, suspended in the water in such quantity that the excess of carbonic acid is neutralised.

Water Permanently Hard.

Calcium sulphate, $CaSO_4$.

This occurs in nature as a mineral, known as *Anhydrite*, and combined with $2H_2O$, as selenite, gypsum, or alabaster. It is soluble in 400 parts of water, and in spring water is a very common impurity, which gives the water permanent hardness, because it cannot be removed by boiling.

Such water curdles soap and prevents easy washing. Water with lime is not good for tea or coffee making. It also is said to increase the liability of the population to calcareous diseases of the kidneys and bladder. Perhaps you will say that lime is useful in the animal organism by way of making bone; true, but was it ordered by nature for us to take too large a quantity in our water, and in the crude form of calcium carbonate roughly into our bodies for bone making. Certainly not. this we should get from the milk and flesh of animals and the outer parts of grain of cereals. However, be this as it may, such water can be softened down by alkali. From my private point of view, I do not set so much strain as my brother science gossips do upon water contaminated with a *little* lime or what is known as good wholesome sound rock, or spring water; providing it is tasteless and clear, I care not how rough it is to drink. In point of fact, I was reared amongst such water, and my parents, and their parents before them, at the same place, and am happy to say that there was never known to be any disease throughout the family.

The late Doctor Clark, of Aberdeen, is credited with being the inventor of bringing lime into water containing carbonate of lime and magnesia, held in solution by excess of carbonic acid. The lime, of course, unites with an excess of carbonic acid, which forms carbonate of lime, so that an insoluble carbonate thus formed, and the carbonate of lime and magnesia will be thrown out of solution and deposited by abstracting the solvent. But you will notice that when water owes its hardness to sulphate of lime or sulphate of magnesia this cannot be so softened. Doctor Clark said, to soften temporarily hard water, or water which can be softened by boiling, that one ounce of quicklime will soften 700 gallons of water, which should be slacked in a little of the water and thrown through a water pot hose into the cistern. After three hours it will be clear enough for washing, and after twelve for drinking.

SULPHURIC ACID.

Should there be sulphuric acid in the water, a precipitate will be the result with the following saline solutions:—

1. Chloride, nitrate, or acetate of barium.
2. ,, ,, ,, strontium.
3. ,, ,, ,, calcium.
4. Nitrate or acetate of lead.

The muriate or chloride of barium is capable of detecting sulphuric acid uncombined to the millionth part of the water. Acetate of lead comes next. The chlorides are more powerful than the nitrates. Calcareous salts are the least effective.

Take note that all these indicate smaller portions of uncombined sulphuric acid than when combined with a base.

You can render barium chloride a certain test for sulphuric acid by the following precautions:—1. The chloride must be diluted. 2. The alkalies or alkaline carbonates, if the water contains any, must be previously saturated with hydrochloric acid. 3. The precipitate must be insoluble in hydrochloric acid. 4. Should boracic acid be suspected, strontium chloride will have to be tried, which is not precipitated by boracic acid. 5. Hydrosulphurets precipitate barytic solutions; their presence can be easily discovered by their stink.

HYDROCHLORIC ACID.

This is discovered in water by nitrate of silver; it gives a white precipitate or a cloud in the water. The following is a certain test:—1. The alkalies or carbonates must be saturated with nitric acid. 2. Should any sulphuric acid be present, it must be first removed by means of nitrate of barytes. 3. The precipitate must be insoluble in nitric acid.

BORACIC ACID.

This is detected with acetate of lead. It forms a precipitate insoluble in acetic acid. But to render the test more certain, the alkalies and earths must be previously saturated with acetic acid, and the sulphuric and hydrochloric acids removed by means of acetate of strontium and acetate of silver.

BARIUM (*continued*).

This is detected by the insoluble white precipitate which it forms with diluted sulphuric acid.

LIMES OR CALCIUM.

These can be detected by means of oxalic acid, which will occasion a white precipitate in the water, containing ever so small portions of this earth. To make sure, should any mineral acids be present, it must be previously saturated with alkali. Should barytes be present, these must previously be removed by sulphuric acid. Magnesia is precipitated by oxalic acid very slowly, but it precipitates lime instantly.

ALUMINA AND MAGNESIA.

Alumina and magnesia are detected as follows. Ammonia (which should be pure) will throw down each, yet no other earth, provided carbonic acid has been previously separated by boiling and a mineral alkali. Lime water only precipitates these two earths, but carbonic acid must have been previously removed, as also the sulphuric acid, by means of nitrate of barytes.

ALUMINA.

If mixed with magnesia can be separated, if precipitated together by boiling the precipitate in pure potass. This dissolves the alumina and leaves the magnesia, and the precipitate may be dissolved in hydrochloric acid precipitated by means of an alkaline carbonate, dried by about 100 degrees of heat. It should then be exposed to the action of hydrochloric acid diluted, which will dissolve the magnesia without affecting the alumina.

SILICA.

The presence of this can be detected by evaporating the water and re-dissolving the precipitate in hydrochloric acid, when the silica will be undissolved.

These are a few well-tried analyses, which [illegible] were practised when I was at South Kensington Museum [illegible]en a School, need no chemical plant to work out, and w[illegible]t [illegible] prove

stepping stones to the following more elaborate Analyses of Mineral Waters.

OLD AND WELL-TRIED ANALYSIS OF MINERAL WATERS.

SECTION 2.

Waters which contain so much foreign matter as to have a sensible taste, and a decided action on the animal economy, are called mineral. Their temperature varies from that of the atmosphere, to almost a boiling heat; and according as it is higher or lower, they have received the denomination of *thermal*, and cold springs. It is not our business to enquire into the remote causes of the remarkable phenomenon of hot springs, but that it must depend on the nature of the strata the waters traverse, from their source to the spot whence they issue, is obvious.

SECTION 3.

The substances hitherto found in mineral waters are:—

Oxygen...	Boracic acid.
Nitrogen	Sulphurous acid.
Carbonic acid	Silica.
Sulphuretted hydrogen	Soda.

Sulphates of soda, ammonia, lime, magnesia, alumina, potassa, iron and copper.

Nitrates of potassa, lime and magnesia.

Hydrochlorates of potassa, soda, ammonia, lime, magnesia, alumina, manganese and baryta.

Carbonates of potassa, soda, magnesia, lime, ammonia and iron.

Hydrosulphurets of soda and lime.

Sub-borate of soda, and small portions of *vegetable* and *animal* substances.

SECTION 4.

Nitrogen and oxygen are not found in waters of a high temperature, nor the latter even in cold springs, which hold hydrosulphurets in solution.

Most waters contain a small portion of carbonic acid, it abounds particularly in the sparkling waters, as those of Seltzer and Pyrmont, which contain many times their bulk of that gas.

A smell, or taste of rotten eggs, indicates the presence of sulphuretted hydrogen, or of a hydrosulphuret. Sulphurous acid is found in some waters in the neighbourhood of volcanoes.

Boracic acid occurs in some of the Italian lakes.

Silica is contained in the waters of the Geysers and Rykum in Iceland, in those of Carlsbad, and in some others.

Soda in the Geysers and at Rykum.

The *salts* of most frequent occurrence in mineral waters are the sulphates, hydrochlorates and carbonates of soda, lime and magnesia, and carbonate of iron. The three last carbonates are generally held in solution by carbonic acid. Hydrochlorate and sulphate of ammonia, sulphate of iron, alum, and sulphate of copper, the nitrates of potassa and lime, and borax, are rarely found in them. The three first, like sulphurous acid, belong to some of them in the neighbourhood of volcanoes; sulphate of copper to those which flow through beds of copper pyrites, and borax to some of the lakes of India and Italy.

Nitrate of magnesia, hydrochlorate and carbonate of potassa, and carbonate of ammonia are of still rarer occurrence, if, indeed, ever found in mineral waters; and, although Bergman has announced the existence of the hydrochlorate of baryta and manganese, and Dr. Withering that of the hydrochlorate of alumina in some of them, the accuracy of the statement is extremely questionable.

SECTION 5.

A mineral water can never contain all the foregoing substances together, as some of them mutually decompose each other; thus, the sub-carbonate of soda is incompatible with the sulphates, nitrates, and hydrochlorates of lime and magnesia: indeed more than eight ingredients are seldom found in the same water, nor does it often contain a large quantity of any one of them.

SECTION 6.

Mineral waters may be conveniently divided into four classes, according to the ingredient by which their properties are chiefly influenced; namely, hepatic, acidulous, ferruginous, and saline; and sometimes mixed classes must be admitted.

The nature of a water, and most of the substances it contains, may generally be ascertained by simple trials; if a water contain

A. *Sulphuretted hydrogen without a hydrosulphuret*, it will have the smell of rotten eggs, and precipitate solutions of lead black, but it loses both these properties by being boiled.

B. A *hydrosulphuret* is attended with the same smell as sulphuretted hydrogen, but weaker; it also precipitates solutions of lead black; but heat does not destroy either of these properties.

C. *Carbonic acid.*—Waters containing this gas are acidulous, and sometimes sparkling; they redden litmus faintly when fresh, but boiling destroys that property, and disengages a gas, which, passed into lime water, occasions a precipitate of carbonate of lime, soluble with effervescence in very dilute nitric acid.

D. *Sulphates* form with nitrate or barium chloride a white precipitate, insolvent in an excess of acid.

E. *Chlorides* produce a white flocculent precipitate with nitrate of silver, insoluble in nitric acid, but soluble in ammonia.

F. *Carbonates of magnesia, lime*, or *iron.*—Waters containing these salts become turbid by boiling; the carbonic acid which holds those substances in solution being driven off. If the precipitate be white, probably no metallic oxide is present.

G. *Carbonate of iron;* with the recent water prussiate of potassa gives a blue precipitate, and tincture of galls a purple one, which, by standing exposed to the air, becomes black. If the water be boiled a yellowish red precipitate is thrown down, and the preceding tests cease to produce any effect on it.

H. *Sulphate of iron.*—The action of prussiate of potassa or galls, is not suspended by boiling the water.

I. *Carbonate of soda*, or *potassa.*—If a water contain either of these alkalies it will turn syrup of violets green after being boiled, at least when sufficiently concentrated, and if then filtered, and an acid be poured into the clear fluid, carbonic acid gas will be given off, though perhaps it may be necessary to heat the water to render it evident, as, if the carbonate be in very minute quantity, the gas may be retained in solution by the cold fluid.

K. *Calcareous salts.*—Oxalate of ammonia throws down a white precipitate from the recent water, if any salt, with base of lime, be present; but if the water contain only carbonate of lime the test will have no effect after boiling: with all the others the effect is permanent.

L. *Magnesian salts, not carbonates.*—Boil and filter the water, and let it cool; to the clear liquid add bi-carbonate of ammonia; filter, if necessary, and boil again. If a sulphate or hydrochlorate of magnesia be present the second boiling will produce a second precipitate; or, after the bi-carbonate, instead of boiling, add phosphate of soda, which will throw down a precipitate of the ammonia-magnesian phosphate; if this precipitate be suffered to

subside to the bottom of the basin, and it be rubbed with the point of a glass rod with some force, traces will be left on the glass not easily effaced. Pure ammonia also renders solutions of magnesian salts turbid.

M. *Aluminous salts.*—Ammonia throws down a bulky gelatinous precipitate, soluble both in sulphuric acid, and in caustic potassa, which contracts extremely on drying, and cracks in all directions. If a few drops of a solution of potassa be added to the acid solution, octohedral crystals of alum will be obtained, by slow evaporation.

N. *Salts of copper.*—Ammonia gives the water a blue tinge; and a plate of iron immersed in it is very soon covered with a coat of copper.

O. *Ammoniacal salts, not carbonates.*—A water containing these salts leaves a residuum after evaporation, which evolves the pungent odour of ammonia on being mixed with quick lime.

P. *Sulphurous acid.*—Waters holding this acid in solution have generally the smell of burning sulphur; they redden *litmus*, and deposit sulphur by the action of sulphuretted hydrogen. When distilled they yield an acid product, which, if neutralised by soda, and exposed to the air, acquires the property of giving a precipitate with nitrate of baryta insoluble in nitric acid.

Q. *Carbonate of ammonia.*—These waters yield an alkaline product by distillation.

R. *Nitrates.*—If a solution of potassa be poured into the water, till no further precipitate falls down, and the liquor filtered and evaporated, a residuum will be obtained which scintillates when thrown on burning coal, like nitre.

When the substances contained in a mineral water are in very minute quantity, it may be necessary to concentrate it considerably by evaporation, to render the effect of the reagents sensible.

SECTION 7.

Only a small number of the preliminary trials enumerated above will be necessary to ascertain the nature of any particular water. The following method is of general application. It consists in first collecting the gases, and next the solid matter contained in the water: the latter is then to be divided into three portions; the first contains all the substances very soluble in water; the second, those soluble in [illegible]: and the third, those insoluble in both. Thus, an otherwise complicated analysis, is rendered simple and easy.

To Collect the Gases.

SECTION 8.

[illegible] *nitrogen* and *oxygen*, adapt a bent tube to a flask and fill [illegible] with water; pass the end of the tube [illegible] inverted over mercury, and heat the [illegible] all the gas is evolved. A little [illegible] should be passed up into the jar [illegible] or sulphuretted hydrogen the [illegible] but the alkali must not be introduced [illegible] if the water be sulphurous, as [illegible] or soda would be liable to [illegible] oxygen gas, if left long in contact [illegible] the whole of these gases, [illegible] be determined by analysis. [illegible] much oxygen and [illegible]

SECTION [illegible].

[illegible] acid; to a matrass [illegible] adapt a glass [illegible] jar, containing a [illegible] and through [illegible] another bent tube, whose opposite extremity must be immersed in water. Fill three-fourths of the matrass with the mineral water, secure all the joints with cement or lute, and heat it gradually till it boils, and continue the ebullition till the whole of the gas has passed over into the alkaline liquor. The carbonic acid will first unite with the ammonia, and the carbonate thus formed will then decompose the hydrochlorate of lime, and a precipitate of carbonate of lime will fall down. This must be carefully collected and dried, and from its weight that of the carbonic acid, and consequently its volume is obtained: 100 parts of carbonate of lime indicate 43·7 parts of carbonic acid, and 100 cubic inches of the gas weigh at the mean temperature and pressure 46·57 grs. The objection to this method is the enormous quantity of water required to afford a sufficient portion of carbonate of lime. Very accurate results may be obtained, by simply receiving the gas over mercury, if the process be carefully conducted: in that case a pint of the water, and even less will be sufficient. If the water contain any carbonate it is probable that they may be in the state of bi-carbonates, especially if the water contain uncombined carbonic acid; and since these give off half their acid at 212°, part of the gas may be derived from that source. This will be ascertained by comparing the quantity of carbonic acid gas evolved, with that of the carbonate obtained in the course of analysis: the bi-carbonates contain twice as much carbonic acid as the carbonates. If the water contain sulphurous acid add a little acetate of lime before it is heated; it would otherwise be partly volatilized, and a portion of insoluble sulphite of lime be mixed with the carbonate.

SECTION 10.

The quantity of *sulphuretted hydrogen* may be ascertained by a similar process, substituting acetate of lead for the ammonia and hydrochlorate of lime; sulphuret of lead will be formed and precipitate in black flakes; but the carbonic acid, if any, will remain free: 100 parts of sulphuret of lead contain 86·6 of lead and 13·4 of sulphur, and 100 cubic inches of sulphuretted hydrogen gas, at mean pressure and temperature, weigh 36 grains; It is easy, therefore, from the weight of the sulphuret to find the quantity of gas. The hydrosulphurets give off sulphuretted hydrogen by heat, but it is easily known if a water contain *only* sulphuretted hydrogen, by its not exhaling the peculiar fetid odour of that gas, on adding hydrochloric acid to a portion of it, that has been boiled; whereas, if a hydrosulphuret be present, it will be abundantly sensible.

The two processes just described, must of necessity be adopted, when a water contains both carbonic acid, and sulphuretted hydrogen; but if it contains only one of them, it is more simple to fill four-fifths of a flask with it, and adapt a bent tube to its neck, which must pass under a mercurial jar, and boil the water for two or three minutes; all the air and carbonic acid, or suphuretted hydrogen, with a small portion of water, will pass into the jar, and being measured, may be separated by caustic potassa, which will absorb the acid gas, but have no action on the common air. The condensed aqueous vapour will indeed retain a small portion of the carbonic acid, or sulphuretted hydrogen, of which it will be easy to take account; for water at the mean barometrical pressure, and temperature of 68° Fahrenheit, dissolves a volume of carbonic acid equal to itself in bulk; and under the same pressure, and at a temperature of 52°, it dissolves three times its volume of sulphuretted hydrogen. Agitate the water in the jar, therefore, as the case may be, with the proper quantity of either gas, and from the whole quantity which pure water would dissolve, under the same circumstances, deduct that actually absorbed: the difference will indicate the quantity already held in solution by the condensed vapour.

SECTION 11.

Sulphurous acid is very rarely found in mineral waters; but if met with, it must be converted by chlorine into sulphuric acid, precipitated by nitrate of baryta, and the sulphate collected, washed, dried, and calcined. 100 parts of this salt represent 27·8 of sulphurous acid by weight: if a water also contain sulphuric acid, or a sulphate, a second portion, to which no chlorine has been added, must likewise be treated with nitrate of baryta, and the weight of this precipitate deducted from the former. 100 parts of sulphate of baryta contain 34 of sulphuric acid.

SECTION 12.

Subcarbonate of ammonia is as seldom found in mineral waters as sulphurous acid. Its quantity may be ascertained by distilling a portion of the water, condensing the vapour in a receiver containing a little hydrochloric acid, and evaporating the liquid to dryness. The quantity of hydrochlorate of ammonia obtained, will give that of the carbonate: 100 parts of the former indicate 73·5 of the latter.

Separation of the Solid Ingredients.

SECTION 13.

If the water contain a hydro-sulphuret, the mode of operating will be different.

Evaporate a sufficient measured quantity of the water, in a tinned copper vessel, until it is reduced to about a pint; then transfer the concentrated liquid to a porcelain basin (taking care to scrape off any solid matter that may adhere to the sides of the copper vessel, and to rinse it with distilled water), and continue the evaporation to dryness. Having thus obtained two or three hundred grains of the residuum, proceed as follows:—

SECTION 14.

A. Boil a certain quantity (100 grains for instance), previously well dried at a temperature not exceeding 212°, with seven or eight times its weight of distilled water, for a few minutes, and if turbid, filter the liquid; wash the filter, and dry and weigh the insoluble matter remaining on it.

B. Evaporate the aqueous solution to dryness; weigh the residuum, and digest it in successive portions of alcohol, of the specific gravity of ·825, with a gentle heat: filter the liquor, and wash the filter repeatedly with alcohol; evaporate the spirit and dry and weigh the residuum.

The fixed ingredients will thus be separated into three portions. Their nature and the means of separating them, must now be considered.

C. The insoluble portion may contain the carbonates of lime, magnesia, and iron, sulphate of lime and silica. Dissolve the carbonates in a very slight excess of weak hydrochloric acid, and separate the undissolved portion by the filter. To the filtered liquid add first a considerable excess of acid, and then ammonia to precipitate the oxide of iron, the weight of which, when dried and ignited, will give that of the carbonate of iron. Next, add subcarbonate of soda to the ammoniacal liquor, which will throw down the lime and magnesia in the state of carbonates; they must be collected and washed, converted into sulphates, and separated as mentioned; their weights will indicate the quantity of their bases respectively, and consequently that of each of the carbonates.

The sulphate of lime, and the silica, may be separated by subcarbonate of potassa and hydrochloric acid. The alkali will decompose the sulphate of lime, and the acid dissolve the carbonate, which is formed, whilst the silica will remain untouched. The sulphate of lime may then be reproduced, by again separating the earth by sub-carbonate of potassa, or soda, and combining the precipitate with sulphuric acid.

D. The hydrochlorates and nitrates of lime and magnesia, soda, hydrosulphuret of soda, hydrochlorate of ammonia, and common salt, are the only substances, soluble in alcohol, likely to be present in a mineral water; and of the two latter alcohol dissolves but a very small quantity. Soda, which, as well as hydrochlorate of ammonia, is of very rare occurrence in mineral waters, is incompatible with magnesian and calcareous salts, and with hydrochlorate of ammonia; so that it can only be found in the alcoholic solution, associated with the hydrochlorate or hydrosulphuret of soda: consequently, when a mineral water contains no sulphuretted hydrogen, which is always easily known, and is most frequently the case, the portion soluble in alcohol will probably consist only of the hydrochlorates and nitrates of lime and magnesia, and hydrochlorate of soda. Dissolve the salts in water, and add an excess of subcarbonate of ammonia, to precipitate the lime and magnesia, in the state of carbonates, whilst their acids will remain in solution, combined with the ammonia. A small portion of magnesia will probably remain not precipitated: to separate which, add a little phosphoric acid; an immediate precipitation of ammonia-magnesian phosphate will ensue. The carbonates and phosphates must be collected *on separate* filters and washed, and the quantities of lime and magnesia of the carbonates ascertained by sulphuric acid, and that of the magnesia, contained in the phosphate, by calcination. 100 parts of calcined phosphate of magnesia contain 40 of magnesia. Next evaporate the liquid containing the common salt, the hydrochlorate, nitrate, and carbonate of ammonia that was added in excess, to dryness, and introduce the residuum into a small retort, from the neck of which a bent tube must pass under, and rise to the top of a receiver full of, and inverted over mercury. Heat the retort gradually; the nitrate of ammonia will be decomposed into water and oxide of nitrogen, and the gas collected in the receiver, and, since as much gas will re-enter the retort on cooling, as was expelled by the heat, what remains in the receiver will exactly represent the quantity of oxide of nitrogen, should the temperature and pressure not to have varied during the operation. When the nitrate of ammonia is completely decomposed, that is when no more gas is disengaged, the retort must be broken, and the hydrochlorates of soda and ammonia collected. Weigh and calcine them at a low red heat, in a platina or silver crucible, to drive off the volatile salt, whose quantity will be indicated by the weight lost in the operation; which, deducted from the whole weight, leaves that of the common salt. The quantity of acid in the hydrochlorates of lime and magnesia will then be ascertained from that of the hydrochlorate of ammonia, and the volume of oxide of nitrogen will give the quantity of the nitric acid.

There is a radical error in this analysis, in the method directed for ascertaining the proportion of the nitrates, by decomposing the nitrate of ammonia by heat. When a mixture of nitrate and hydrochlorate of ammonia is exposed in a retort to a heat sufficient to decompose the nitrate, a mutual action takes place between the two salts, and a gaseous mixture, containing a large quantity of chlorine, is obtained: as is evident, both from its peculiar odour, from its action on mercury, and from its power to discharge vegetable colours. I have not examined the composit[illegible] the gas evolved, but it is clear that the acid of the l[illegible] chlorate must be decomposed, and consequently the [illegible] defective. Did its decomposition not take place, i[illegible] be difficult to prevent some of the hydrochlorate f[illegible] volatilized in the operation.

Perhaps the following scheme may be practicable for the analysis of the compound

To the solution of the hydrochlorates and nitrates of lime and magnesia, and hydrochlorate of soda, add cautiously, drop by drop, acetate of silver, until no further precipitate ensues, avoiding as much as possible any excess of the precipitant. The whole of the hydrochloric acid will thus be separated, and there will remain in solution the acetates of lime, magnesia, and soda, and the nitrates of lime and magnesia. Evaporate to dryness by a gentle heat, taking care not to decompose the acetates by too high a temperature. Digest the dry mass in rather less than twice its weight of cold alcohol of the specific gravity at least of ·850, or better if even ·820. This will dissolve the acetates and nitrates of lime and magnesia, and leave the acetate of soda. Decant off the alcoholic solutions, wash the residuum with fresh alcohol, and add the washings to the decanted portion. The acetate of soda may then be converted into subcarbonate by a red heat, and weighed.

Distil off the alcohol from the dissolved salts, redissolve them in water, and to the solution add subcarbonate of potassa, avoiding unnecessary excess: this will throw down the lime and magnesia in the state of carbonates, and leave in solution acetate and nitrate of potassa and a small portion of carbonate of potassa. Separate the precipitate, evaporate the solution again to dryness, and boil the residuum in alcohol of ·820, which will dissolve the acetate of potassa, and leave the nitrate and sub-carbonate. Separate the spirituous solution, and distil it to dryness, and convert the sub-carbonate of potassa into acetate, by pure weak acetic acid. A repetition of the action of alcohol, of the same specific gravity as the former, will then separate the acetate, and the nitrate of potassa will be left insulated. By the first process we get chloride of silver, from whence the whole quantity of hydrochloric acid is obtained; by the second sub-carbonate of soda, which denotes the quantity of acid in the hydrochlorate of soda; by the third, the carbonates of lime and magnesia, whence we learn the weight of those bases; and from the weight of the nitrate of potassa of the last process, we find the quantity of nitric acid. From these data the proportions of the several salts in the mixture may be estimated.

100 chloride of silver are	equivalent to	25·46 hydrochloric acid
100 nitrate of potassa ,,	,,	52·88 nitric acid
100 subcarbonate of soda	,,	110· common salt
or	,,	68·7 hydrochloric acid
100 carbonate of lime ,,	,,	56· lime
100 carbonate of magnesia	,,	47· magnesia

The quantities of lime and magnesia, which saturate equal portions of hydrochloric and nitric acids, are given above.

From these several data, and from the quantities of lime and magnesia, which are already known, it will not be difficult to estimate the respective proportions of the calcareous and magnesian hydrochlorates and nitrates.

100 parts of nitric acid saturate	52·5 lime
,, ,, ,,	36·5 magnesia
100 parts of hydrochloric acid saturate	102· lime
,, ,, ,, ,,	72·3 magnesia

100 parts of hydrochlorate of ammonia contain 51 hydrochloric acid, 100 cubic inches of oxide of nitrogen weigh 46·125 grains; and 100 parts by weight, of the oxide, indicate 123·17 parts of nitric acid.

Instead of treating the whole solution (after the separation of the lime and magnesia, by sub-carbonate of ammonia) in the manner just mentioned, a moiety of it may be submitted to a different process, as follows:—

Digest the solution, freed from the carbonate of ammonia by boiling, on phosphate of silver in excess: chloride of silver, and phosphates of soda and ammonia will be formed. The two last salts will remain in solution, with the nitrate of ammonia; but the chloride of silver, with the excess of phosphate of silver, fall down.

Nitric acid will take up the latter, and leave the chloride, whose weight may then be ascertained. Next pour subcarbonate of soda into the filtered liquor, in order to convert the phosphate and nitrate of ammonia into phosphate and nitrate of soda; then evaporate to dryness, and heat the residuum with alcohol of the specific gravity of ·850, which will dissolve the nitrate of soda, but have no action on the other salts. The quantity of dry nitrate of soda will give that of the nitric acid, and the quantity of chloride of silver that of the hydrochloric acid of the hydrochlorates of soda, lime and magnesia; and since the quantity of common salt, and consequently that of its acid, is already known by the first process, deducting the latter from the whole quantity of hydrochloric acid, the quantity of the acid of the hydrochlorates of lime and magnesia is obtained.

By thus varying the processes, the quantities of the nitric and hydrochloric acids are obtained in different ways, and the results, if they harmonise, entitled to the greater confidence.

Section 15.

The substances soluble in water only are more numerous than the preceding; they amount to thirteen, namely, the sulphates of soda, magnesia, ammonia, iron and copper, and alum; nitrate of potassa, the hydrochlorates of potassa and soda; the sub-borate of soda and boracic acid.

Although common salt has been classed with the substances soluble in alcohol, it is necessary to place it also with those insoluble in that agent, which takes up so small a portion that it commonly makes part of both classes.

Nitrate of potassa is distinguished from all the rest by scintillating when thrown on red hot charcoal; boracic acid by the beautiful green colour it imparts to the flame of burning alcohol: and alum by ammonia throwing down its alumina. The form of the crystals of sulphate of soda is a six-sided prism, with dihedral summits; that of nitre, a six-sided prism, terminated by six-sided pyramids. Boracic acid crystallises in thin hexagonal plates, and alum in regular octohedra.

Section 16.

The sulphates of magnesia, ammonia, iron, and copper, and the hydrochlorates and carbonates of potassa and soda are known by the characters already described at Section 6. Sulphate of soda, nitrate of potassa, boracic acid, and alum, by solution in water and crystallisation, and borax by sulphuric acid precipitating boracic acid, form a concentrated solution of that salt.

Section 17.

The sulphates of ammonia, iron and copper, alum, nitrate, hydrochlorate and carbonate of potassa, borax and boracic acid, are very rarely found in mineral waters, and carbonate of soda or potassa is incompatible with sulphate of copper and free boracic acid. Thus the sulphates of soda and magnesia, common salt and carbonate of soda, are almost the only substances of this class likely to be met with; moreover, only three of them can exist together, for sulphate of magnesia and carbonate of soda mutually decompose each other.

Section 18.

Suppose, first, there be no sulphate of magnesia in the water; treat the mixture with successive portions of alcohol of the specific gravity of ·875, which will dissolve all the common salt; then, adding acetic acid to the sulphate and carbonate of soda, the latter will be converted into an acetate, soluble in alcohol, and thus easily separated from the sulphate—the quantity of acetate will give that of the carbonate.

Section 19.

Secondly, suppose there be no carbonate of soda present; the sea salt is to be separated, as before, by alcohol; then dissolve the residuum in water and add barium chloride till it produces no further precipitate, taking great care not to add it in excess. The sulphates of soda and magnesia will be decomposed, insoluble sulphate of barium will fall down, and the hydrochlorates of soda and magnesia remain in solution. Evaporate the liquid to dryness, and calcine the residuum in a platina crucible at a red heat. The hydrochlorate of magnesia will thus be deprived of its acid, and the common salt may be separated from the magnesia by water. 100 parts of common salt are equivalent to 53·25 of soda. From the quantities of soda and magnesia, the quantities of their sulphates may be estimated, and the weight of the sulphuric acid from that of the sulphate of barium.

Section 20.

If a mineral water contain a hydrosulphuret—the hydrosulphuret is never pure, it is always more or less sulphuretted.

A. Collect the gases, as stated at Section 8.

B. The carbonates of lime and magnesia, the sulphate of lime, and the silica must also be separated by the usual methods, except that it is better to evaporate the water in a retort than in a basin, to prevent the action of the air on the hydrosulphuret.

C. To ascertain the quantity of the hydrosulphuret (or, more properly, sulphuretted hydrosulphuret) introduce the water into a tubulated retort, having a tube of safety fitted to the tubulure, and a common tube to its neck, which must pass into a flask containing acetate of lead; pour acetic acid into the water through the tube of safety, and heat it gradually till it boils. The hydrosulphuret will be decomposed; its sulphuretted hydrogen will pass into the flask and produce sulphuret of lead, and the sulphur that was united with the hydrosulphuret will be precipitated. From the weight of the sulphuret we obtain that of the sulphuretted hydrogen, and from the weight of the latter and the sulphur, that of the sulphuretted hydrosulphuret.

It would be better, and it is sometimes possible, to determine the quantity of the base of the sulphuretted hydrosulphuret in a direct manner, than to deduce it from the weight of the sulphuretted hydrogen and the sulphur, particularly as the latter is difficult to collect.

This process supposes the water to contain no free sulphuretted hydrogen; if that be the case, which will be known by its smell, it must first be driven off by a gentle heat.

100 of lead combine with 15·5 of sulphur, and 15 of sulphur with one of hydrogen. The sulphuretted hydrosulphurets (hydroguretted sulphurets) are probably formed of two atoms of sulphur, one of hydrogen, and one of base; thus, if it be the sulphuretted hydrosulphuret of soda (or more properly of sodium), its composition would be sodium 22. sulphur 30, hydrogen $1 = 53$.

D. The quantity of carbonate of soda may be determined by a similar process. After boiling the water, to throw down the insoluble carbonates, filter and treat it with hydrochloric acid, in an apparatus like that mentioned, containing a solution of ammonia and hydrochlorate of lime, in the manner there directed; from the weight of the carbonate of lime that of the alkaline salt will be deduced. 100 parts of carbonate of lime are equivalent to 105·5 parts of sub-carbonate of soda, deprived of its water by a red heat, and to 168 parts of the crystallised bi-carbonate.

E. It remains to consider how the other substances are to be separated. If carbonate of soda be present, the water can contain besides only the carbonates of lime and magnesia, silica, hydrosulphuret of soda, and other salts with base of that alkali. In that case add an excess of acetic acid and evaporate to dryness, calcine the residuum at a red heat, affuse water on it, and filter the liquor. The soda of the carbonate and hydrosulphuret, and the other salts (generally only sulphate and hydrochlorate of soda) will be dissolved.

To the solution add sub-carbonate of ammonia to convert the soda completely into sub-carbonate, and boil the liquid to drive off the excess of the volatile carbonate, and then proceed to ascertain the quantities of sea salt and sulphate of soda, by alcohol and acetic acid, as directed. At the same time the quantity of acetate must be ascertained, which will give that of the soda, and the quantities of carbonic acid and sulphuretted hydrogen those of the hydrosulphuret and sub-carbonate.

F. If no carbonate of soda be present, a mineral water may contain, in addition to the substances mentioned in the last paragraph, the sulphates, hydrochlorates and nitrates of lime and magnesia. In this case agitate it with an excess of chloride of mercury (calomel), which will decompose the hydrosulphuret and an insoluble black sulphuret of mercury, and hydrochlorate of lime or soda, according as the sulphuretted hydrogen was united to one or other of those two bases, will be formed. To complete the analysis, observe the directions contained in the Sections 13, *et seq.*; but, from the quantity of hydrochlorate obtained, must be deducted that which arises from the action of the hydrosulphuret on the chloride of mercury. For this purpose take a fresh portion of the water, add nitric acid, and boil it to expel the sulphuretted hydrogen; then filter and drop in an excess of sulphate of silver. As a sulphate may be present this is preferable to nitrate of silver. The weight of the chloride of silver that will be formed will indicate the real quantity of the acid contained in the water, whence that arising from the calomel may be estimated. Since the sum of the two quantities have been given by the first experiment, and the quantity of acid derived from the chloride is also known, the quantity of base which saturates it is likewise obtained. The quantity of hydrosulphuret will likewise be found from the same data, as it is the result of the union of that base with the sulphuretted hydrogen.

Section 21.

In all cases it is right in the first instance to devote a portion of the water to an inquiry into the nature of its contents before the more perfect analysis is undertaken.

In addition to the preceding directions in this work, an example of the actual analysis of a mineral water, cannot fail to be extremely useful to the student in this intricate and difficult part of our subject. And I know none better calculated for the purpose than the ingenious and accurate one of the celebrated Bath water, by the late Mr. Richard Phillips, in which it will be seen how attentively the phenomena produced by the different reagents must be observed, and how cautiously the inferences they appear to lead to, adopted.

Analysis of the Hot Springs at Bath.

(*Also see Geysers.*)

The nature of the country round Bath, and other local circumstances, have been so fully described by those who have given chemical examinations of the waters of the hot springs at that place, that any further description appears unnecessary.

As to the cause of the heat of these springs, we have so few data from which to reason, that I shall not offer even a conjecture on the subject.

These waters have been frequently analysed. They have merited the attention they have received, not only from their early and extensive employment in the cure of diseases, but also on account of some peculiar changes to

which they are subject. Of these the explanations have been so various as to show that they require still further examination.

Of the sensible properties exhibited by these waters the most remarkable is their high temperature, the degree of which varies considerably at their different sources. At the hot bath it is 117°; at the king's bath 114°; and at the cross bath 109°. This statement does not exactly agree with what has been usually given as their temperature. These results were obtained by pumping the water upon the bulb of a thermometer till the mercury ceased to rise. Their taste is metallic, but not strongly or disagreeably so; this has not been universally allowed: but if they are drank hot, this impression is readily distinguishable.

Their specific gravity is 1·002 at each of the springs; and as the effects produced by chemical tests are also perfectly similar, they may be considered as derived from one source, the temperature varying by their more or less circuitous passage to the surface. For the purpose of analysis the water of the king's bath has been usually employed; and although it does not appear to be a matter of much importance, I have followed the usual practice.

Before the experiments made upon the water are related, it will be necessary to state those employed to ascertain the proportions of the gas, which rises in great quantity through the water in the king's bath.

This gas is perfectly free from smell.

A. Some of the gas was received into a jar. A lighted taper put into it was immediately extinguished.

B. Received into lime water, it caused an immediate precipitation.

C. Tincture of litmus suffered no change of colour by agitation with the gas.

D. The colour of dilute tincture of turmeric and tincture of galls was destroyed by it.

From these effects the gas appears to consist principally of nitrogen gas with a small portion of carbonic acid gas. To ascertain the quantity of each, and whether any oxygen gas was present, the following experiments were performed:—

E. One hundred measures of the gas were strongly agitated with barytes water in a graduated tube. A considerable precipitate was deposited, and five measures were absorbed.

F. One measure of deutoxide of nitrogen was added to an equal quantity of the gas in an eudiometer in the water apparatus. The mixed gases underwent no alteration of colour nor diminution of volume.

G. One hundred measures of the gas which had been deprived of carbonic acid by barytes water were submitted to the action of solution of protomuriate of iron impregnated with deutoxide of nitrogen. No absorption took place.

This gas, therefore, consists of—

Carbonic acid gas	5
Nitrogen gas...	95
	100

I now proceeded to try whether the water held either of those gases in solution.

H. Ten ounces of the water which had been cooled in a well-closed bottle, were put into a vessel furnished with a bent tube; the water was boiled for about twenty minutes, and the gas evolved from the water and the air of the tube, except a quantity too small to be estimated, were received in a graduated jar over mercury. Solution of potash absorbed three-fourths of an inch of this gas, which was carbonic acid.

I. The unabsorbed gas was transferred to the water apparatus, and tried in the usual way with deutoxide of nitrogen. The mean result of comparative experiments upon it and atmospheric air showed that it was merely the air of the vessel, and that no nitrogen gas was held in solution by the water.

As ten ounces of the water gave ·75 of an inch of carbonic acid, one quart would furnish 2·4. This quantity is not quite exact, it being scarcely possible to obtain the whole of the carbonic acid by ebullition.

Effects of Atmospheric Air and Reagents.

K. Some of the water, while hot, having been exposed in a vessel of broad surface to the atmosphere, afforded in a few hours a small quantity of a white precipitate; but water which had been cooled in a close vessel remained perfectly transparent after several weeks' exposure to the air.

The reagents added to the water while hot, and the effects produced by them, were the following:—

L. Acetate of lead—a perfectly white precipitate.

M. Tincture of litmus—no alteration of colour.

N. Tincture of turmeric—no change indicating the presence of uncombined alkali; its colour immediately destroyed.

O. Lime water—a white precipitate.

P. Potash—a white precipitate.

Q. Carbonate of potash—a white precipitate.

R. Some of the water was boiled with a little nitric acid—potash added to this gave no precipitate.

S. Oxalate of ammonia—a precipitate.

T. Nitrate of barytes—a precipitate insoluble in nitric acid.

U. Nitrate of silver—a white precipitate insoluble in nitric acid.

V. Solution of sulphuretted hydrogen—no precipitate nor change of colour; the water became very slightly turbid.

W. Prussiate of potash—no immediate effect: after some weeks the water became slightly green.

X. Tincture of galls—immediately a peach-blossom red colour, and very soon a precipitate which became dark purple by exposure to the air.

All the above effects are also produced after the water has been cooled, excepting that the colour of tincture of turmeric is not then destroyed, and, under some circumstances, no red colour occurs upon the addition of tincture of galls.

Y. A quantity of the water was evaporated to dryness, and distilled water added to the residuum. Nitrate of lime poured into the solution afforded a crystalline precipitate in a few hours, indicating the presence of an alkaline sulphate.

I shall now state the inferences to be deduced from these experiments.

Carbonic acid exists in this water (B, E). A considerable portion of it escapes at the high temperature at which the water is obtained, its evolution occasioning the precipitation of some substance which it held in solution (K).

From experiment (L) it is evident that no sulphuretted hydrogen gas is present.

As no alteration of colour is effected upon tincture of litmus by the carbonic acid (M), it is evident that this acid is present only in sufficient quantity to dissolve the substance precipitated by its evolution.

The destruction of the colour of tincture of turmeric (N) is clearly occasioned by the gas during its passage through the water (D).

The effect produced in experiment (O) is owing to the formation of carbonate of lime, and the precipitation of it and of the substance previously dissolved by carbonic acid (K).

A part of the precipitate obtained by adding potash (P) must have been similar to that of experiment (K), and to a portion [illegible] riment (O), produced in (P) and (O)

by combining the solvent carbonic acid instead of expelling it as in experiment (K). The precipitate was carbonate of lime, or of magnesia, or both.

As earthy carbonates are not precipitable by alkaline carbonates, the precipitate formed by carbonate of potash (Q) indicates the presence of some other earthy salt.

From experiment (R) it appears that no alumina nor magnesia exists in the water, and that the precipitate obtained in experiment (K) was carbonate of lime.

Experiment (S) determines the presence of lime.

Experiment (T) shows that sulphuric acid exists in the water.

The effect produced by nitrate of silver (U) results from the action of hydrochloric acid.

As no metallic oxide discoverable by sulphuretted hydrogen was suspected, the appearance it produced (V) was supposed to be derived from its action upon carbonate of lime. This was ascertained to be the case by direct experiment.

As the prussiate of potash employed in experiment (W) contains oxide of iron as one of its constituents, it was imagined that the slight greenness which was assumed by the water might be occasioned by the action of the carbonic acid, notwithstanding its holding carbonate of lime in solution, this effect being easily produced by the application of the stronger acids. A small quantity of the triple prussiate was therefore added to a solution of carbonate of lime in carbonic acid: after a considerable time it acquired a green colour, exactly similar to that observed in experiment (W). Dr. Falconer has, indeed, stated that a blue colour is to be obtained by the action of prussiate of potash upon the water; but, as it did not occur till after the addition of sulphuric acid, it is evident that this effect was produced by the action of the acid upon the oxide of iron of the prussiate.

Although the presence of oxide of iron is not at all indicated by prussiate of potash (probably on account of the smallness of its quantity), yet it is evident from the action of tincture of galls (X) that a minute portion of it actually exists in the water; the light colour of the recent precipitate, and its becoming darker by contact with atmospheric air, showing that it is in the state of protoxide. In making this experiment it is requisite to use a very small quantity of the tincture of galls; for, if much more than five drops of it are added to one ounce of the water, no indication of oxide of iron is produced, the water becoming of a light reddish brown colour, and affording no precipitate. An excess of this tincture reacts upon the compound of vegetable matter and oxide of iron so completely as to prevent the appearances readily presented by a small quantity.

From the well-known laws of chemical affinity it is evident that the oxide of iron is combined with carbonic acid; this compound undergoing some curious changes, which have occasioned much discussion.

It has been observed that one of the most active tests of oxide of iron does not in this water produce any appearance of its presence; and the slight metallic taste which it communicates when hot and fresh has been unnoticed by some analysts. This taste is lost by cooling, even in well-stopped bottles; and every method which I have tried to restore it has been unsuccessful. It has also been mentioned that the action of tincture of galls is in some cases lost; and this fact has occasioned much discussion respecting the oxide of iron. The following experiments will show under what circumstances this occurs:—

a. About one pint of the water was exposed, while hot, to the atmosphere in a vessel of broad surface. After it had remained about sixteen hours, a small quantity of carbonate of lime was deposited by the evolution of carbonic acid gas. The precipitate was perfectly white, and had not the slightest appearance of containing oxide of iron. To this water tincture of galls was added without occasioning the least alteration of colour.

b. As the quantity of oxide of iron in the water is evidently extremely small, it may be imagined that it was precipitated with the carbonate of lime, but escaped observation from the minuteness of the quantity. To obviate this objection, some of the water was closely stopped in a vial for four or five days: upon examination it was found to possess its transparency perfectly, and without having afforded any precipitate; to some of this tincture of galls was added without producing the slightest indication of oxide of iron.

c. Some of the water, which had been cooled so as to retain its transparency, was heated to its original temperature; tincture of galls was then added, but without producing any effect.

The facts exhibited in experiments (*b*) and (*c*) have been long known, and have given rise to an idea that the iron is volatilised. Although this opinion is incompatible with facts already mentioned, yet it may not be amiss to show more particularly that it is completely erroneous. As it cannot be imagined that the temperature of the water is sufficient to volatilise mere oxide of iron, the existence of some substance capable of carrying it off must have been supposed. That muriatic acid and muriate of ammonia possess this power at high temperatures is well known, but no muriate of ammonia is present, nor is any muriatic acid, except in combination. Hydrogen gas is said also to be capable of volatilising iron; but the gas evolved from the water has been shown to consist of nitrogen gas and a small quantity of carbonic acid gas, and to these gases, either separate or combined, no such power has ever been attributed. If, however, they really possess it in this instance, they must be regarded as the solvent of the iron, and the effect produced upon tincture of galls must be derived from the gas diffused in small quantities through the water. If this be the case, the application of the concentrated solution of iron should produce a much more distinct effect upon the tincture; but it has been shown (D) that the gas destroys the colour of tincture of galls instead of increasing it, which would be the effect if it contained oxide of iron.

d. About one gallon of the water was put into a vessel of considerable depth, of which it occupied about two-thirds: it was slightly covered, and remained about twenty-four hours. It then retained its power of affording a peach-blossom coloured precipitate with tincture of galls (X) in a very considerable degree.

It is remarkable that in this experiment the result should have proved so different from that obtained in one where the circumstances were similar, excepting only the form of the vessel and the quantity of the water. When the water was exposed with a broad surface, tincture of galls showed no action on it (*a*); but in this case, even after eight hours' longer exposure, it detected oxide of iron.

From this circumstance I began to suspect that some change was produced by the absorption of oxygen, and that it had not produced the same effect in this as in the former experiment, on account of the quantity of the water and depth of the vessel. There appeared, however, a strong fact against this supposition, viz., that iron is more easily detected when highly oxidised, whereas the contrary effect was in this case produced.

To try the effect of atmospheric air, the following experiments were performed:—

e. A small quantity of the water was enclosed, w hot, in a well-stopped vial, with about one-fortieth volume of atmospheric air. After four days the remained perfectly transparent, but the addition of tin of galls did not afford the slightest appearance of containing iron.

f. Another portion of the water was kept for the same length of time in a well-stopped vial, but without any air, except such as the water held in solution. Tincture of galls occasioned exactly the same appearance of iron in this as in the water when fresh and hot (X).

That the action of tincture of galls is lost by the absorption of the oxygen of atmospheric air is proved by the following experiment:—

g. A third quantity of the water was enclosed, with the usual precaution, in a vial, about one-half of which was occupied by the gas evolved from the water in the bath, which has been shown to contain no oxygen gas. After four days, tincture of galls was added to it, and gave the same appearances of oxide of iron as occur in its application to the fresh hot water.

Having thus ascertained the effect of oxygen in preventing the action of tincture of galls upon oxide of iron, it remained to be shown in what manner this is effected. I imagined it might be produced by increasing the power of combination of the oxide of iron so as to admit of its acting upon the earthy contents of the water and forming compounds, the strong affinity of the constituents of which prevented the action of the tincture of galls. With a view to ascertain how far this supposition was correct, I examined the effects produced by adding carbonate of lime, dissolved by carbonic acid, to solution of sulphate of iron to which tincture of galls had been previously added; and although it will appear, by the following experiments, that the alterations produced upon the oxide of iron in the water are caused by the carbonate of lime it contains, it will also be found that they are not effected in the way I had supposed.

A very dilute solution of protosulphate of iron was prepared. The quantity of oxide of iron contained in it was so small as scarcely to afford any alteration of colour when tincture of galls was added to it; but upon pouring solution of carbonate of lime into it after tincture of galls had been added, a deep red colour was almost instantaneously produced.

Although this fact did not immediately appear likely to solve the difficulties attendant upon the water in question, yet it was sufficiently striking to merit an examination by what means the carbonate of lime produced this effect, and to what extent it might be employed in rendering tincture of galls a more active reagent.

With this intention I boiled some crystallised sulphate of iron in alcohol till nearly the whole of the persulphate was separated. The remaining quantity being extremely small, I shall consider the iron in this solution as entirely in the state of protoxide. The sulphate, insoluble in alcohol, was dissolved in water, and the quantity of the oxide contained in a given portion of the solution was ascertained by taking the average of two experiments.

[illegible] To one ounce of this solution, containing about $\frac{1}{500}$th of a grain of protoxide of iron, tincture of galls was added. [illegible] the usual appearance indicated by the [illegible] oxide of iron in a very slight degree. The [illegible] increased by the absorption of the oxygen of the atmosphere.

[illegible] quantity of the solution was treated with [illegible] potash. A light blue colour was immediately [illegible] by the minute portion of peroxide of iron which [illegible] the alcohol. The intensity of [illegible] increased by the action of atmospheric [illegible] converted into peroxide.

[illegible] was added to one ounce of a dilute [illegible] of lime containing about $\frac{1}{500}$th of a [illegible] in the former experiments. A red purple [illegible] intensity, was immediately [illegible]

[illegible] The last experiment was repeated, employing only [illegible] instead of $\frac{1}{500}$th. A very distinct red purple was immediately produced by the action of the tincture of galls.

m. To one ounce of a solution of carbonate of lime, containing $\frac{1}{500}$th of a grain of oxide of iron, prussiate of potash was added; but it did not produce any indication of having acted upon the oxide of iron.

I now prepared a solution of persulphate of iron by treating the protosulphate with nitric acid in a red heat. The quantity of oxide which the solution contained was as in the former case ascertained. The experiments made with this were as follow:—

n. One ounce of a solution of persulphate of iron, containing $\frac{1}{1000}$th of a grain of oxide, was treated with tincture of galls. The usual indications of its action upon oxide of iron were presented.

o. The addition of prussiate of potash to an equal quantity of the solution immediately occasioned a blue colour.

p. Tincture of galls was added to one ounce of a dilute solution of carbonate of lime containing $\frac{1}{1000}$th of a grain of the peroxide of iron. Slight indications of its action upon the oxide were produced, but the colour was scarcely more intense than that effected by $\frac{1}{5000}$th of a grain of protoxide in similar circumstances. No effect whatever was produced by infusion of galls upon $\frac{1}{10000}$th of a grain of peroxide in one ounce of solution of carbonate of lime. The colour produced when carbonate of lime and tincture of galls are added to the peroxide is reddish purple, similar to that occasioned by their action upon the protoxide.

q. To one ounce of a solution of carbonate of lime, containing, as in the last experiment, $\frac{1}{1000}$th of a grain of peroxide of iron, prussiate of potash was added. Not the slightest blue colour was produced. When carbonate of lime was thus added to the solution of peroxide of iron, I found that it was capable of preventing the action of prussiate of potash upon $\frac{1}{250}$th of a grain.

From these experiments it is evident that carbonate of lime possesses, in a very great degree, the power of increasing the action of tincture of galls upon protoxide of iron; while, on the contrary, it diminishes its power in detecting peroxide of iron, and is, moreover, capable of preventing the action of prussiate of potash, to a certain extent.

The application of these experiments to the circumstances of the water in question is obvious. It has been shown that it contains carbonate of lime; and that the power of tincture of galls to detect the oxide of iron it contains is completely lost by the absorption of oxygen. The following experiment was made with the intention of trying whether this effect of slow oxidisement might be imitated.

r. Tincture of galls is, as has been seen, capable of acting upon $\frac{1}{5000}$th of a grain of protoxide of iron in one ounce of solution of carbonate of lime (*l*). A portion of sulphate of iron, containing $\frac{1}{5000}$th of a grain of protoxide, was dissolved in one ounce of dilute solution of carbonate of lime, and was kept in contact, with about one-fourth of its volume of atmospheric air, during twenty-four hours. At the end of that time the solution remained perfectly transparent, nor had any precipitation occurred in it. But the addition of tincture of galls did not occasion the slightest appearance of having acted upon the oxide of iron. In this experiment the loss of power of tincture of galls is much more speedily effected than in the Bath water. This is evidently owing to the atmospheric air contained in the distilled water employed, whereas no oxygen gas is present in the Bath water.

When carbonate of lime is added to sulphate of iron it is well known that double decomposition takes place, the iron being thus combined with the carbonic acid instead of the sulphuric. Having found that tincture of galls, in several instances, acts much more readily upon carbonates than sulphates, I imagined that the carbonate of lime produced its effect in this way. To ascertain whether this supposition was correct, I made the following experiment:—

s. A quantity of the solution of protosulphate of iron, similar to that employed in the above-related experiments, was decomposed by carbonate of potash; carbonic acid gas was passed through water in which the washed carbonate of iron was diffused, and to some of the filtered solution tincture of galls was added; but, instead of the reddish purple colour effected by the action of carbonate of lime upon sulphate of iron and tincture of galls (*k*) and (*l*), the usual deep blue colour was produced.

t. One-tenth of the quantity of carbonate of iron employed in the last experiment was dissolved in a solution of carbonate of lime equal in measure to the last solution. To this tincture of galls was added. The reddish purple colour was immediately produced, and from its intensity it was evident that carbonate of lime had increased the power of tincture of galls as much in employing the carbonate as the sulphate of iron.

It may be concluded, from these experiments, that the effects produced by carbonate of lime are not attributable to the conversion of the sulphate of iron into a carbonate; and I have found that alkalies and their carbonates possess the peculiar power of increasing the mutual affinity and action between tincture of galls and protoxide of iron.

I next examined the salts produced by evaporating the water and crystallisation.

u. A quantity of the water was evaporated to dryness. The residuum was treated with distilled water as long as that fluid continued to dissolve any portion of it. This solution was again evaporated, and upon cooling yielded a considerable quantity of acicular crystals. These were again dissolved in distilled water; and to a part of the solution nitrate of barytes was added, which occasioned a copious precipitate. The same effect was produced by oxalate of ammonia; but ammonia caused no precipitation. These crystals were therefore sulphate of lime. By further evaporation the solution afforded cubic crystals of common salt and prismatic crystals of sulphate of soda.

The next object to be attained was the weight of the total quantity of the various substances held in solution by a given portion of the water. This has been given with considerable variation, by different analysts, as will appear by the following statement. From a quart of the water

Dr. Lucas	obtained	33½	grains of dry residuum.
Dr. Charlton	,,	34	,, ,,
Dr. Falconer	,,	17¾	,, ,,
Dr. Gibbes	,,	23¼	,, ,,

To account for the great difference of these results, Dr. Saunders has supposed that the water varies at different times, or that the residuum has been dried with various degrees of heat. I have ascertained the quantity of the contents of the water several times during about eighteen months, without observing any other variation in its weight than is unavoidable in experiment. In support of this observation, it may be remarked that I found its specific gravity exactly as stated by Dr. Falconer.

It is scarcely probable that the results of any of these analyses were obtained by drying the residuum at a lower temperature than 212°, or at a greater than a red heat. Now I find that one quart of the water, weighing 30 troy ounces 172 grains, at the temperature of 63°, gives 32 grains of residuum dried at 212°: when the heat of a sand-bath is employed, 30 grains are obtained; and at a red heat, 28 grains. The greatest variation afforded by these methods is four grains, whereas from some cause, which it is difficult to explain, the extreme difference of the experiments above cited is 16¼ grains. When a red heat is employed, a part of the loss is occasioned by the decomposition of the carbonate of lime; for water poured upon the residuum turns turmeric paper of a reddish-brown colour. The greater part of the residuum is perfectly white; the portion deposited at the upper part of the vessel is, however, slightly greyish, but not at all appearing as if coloured by oxide of iron. I suspected that it might be occasioned by carbonaceous matter: to ascertain whether this was the case, the following experiment was made:

v. Four pints of the water were evaporated to dryness in a retort, and the residuum boiled with about five ounces of alcohol. The filtered solution left, on evaporation, 8·3 grains of a yellowish coloured substance. A part of this was dissolved in water, and afforded a copious white precipitate with nitrate of silver, but did not give any with ammonia or with carbonate of ammonia: common salt was therefore the only one dissolved by the alcohol.

w. To the remaining portion of the saline mass colourless sulphuric acid was added. By heating, the acid acquired a dark brown colour, evidently derived from its action upon carbonaceous matter. This experiment did not appear conclusive, as two causes of error might have existed,—a small quantity of alcohol was probably decomposed by the action of the salts upon it, or some of the conferva which is found in the water might have escaped notice previous to evaporation. I had recourse, therefore, to other means. Mr. Kirwan, in his "Treatise on the Analysis of Mineral Waters," gives a method for ascertaining the presence and quantity of extractive matter proposed by Westrumb, which consists in precipitating the chlorine salts by nitrate of lead, and afterwards the extractive matter by nitrate of silver. It is impossible to conceive any method more completely fallacious than this; for extractive matter is as readily precipitated by nitrate of lead as by nitrate of silver; and although common salt is decomposed by nitrate of lead, chloride of lead being a salt of considerable solubility, the subsequent addition of nitrate of silver would decompose it, and afford a precipitate consisting of chloride of silver without any extractive matter.

The power of sulphuric acid in detecting carbonaceous matter is extremely great: $\frac{1}{100}$th of a grain of sugar was dissolved in four ounces of water; to this solution about one ounce of sulphuric acid was added: it was then boiled till nearly the whole of the water was evaporated, and the acid had acquired a very distinct brown colour.

The following experiment was now made:

x. A quantity of sulphuric acid was added to one quart of water perfectly transparent, and free from heterogeneous matter. The mixture was evaporated nearly to dryness in a retort, and the sulphuric acid remained perfectly colourless. The water, therefore, contains no carbonaceous matter.

The substances contained in the water, as shown by the foregoing experiments, are: carbonate of lime, oxide of iron, sulphate of lime, common salt, and sulphate of soda. The presence of these compounds has been universally allowed; but that silica was contained in the water was discovered by Dr. Gibbes. To find the quantity of each of these, the following methods were employed:

y. A quart of the water was evaporated to dryness in a platina crucible: the residuum, dried in a sand heat, weighed thirty grains. This was boiled, with successive portions of distilled water, till it ceased to afford a precipitate with nitrate of barytes. The solution was then divided into three equal quantities.

z. To one of these portions nitrate of silver was added as long as precipitation took place, and distilled water was poured upon the precipitate till it came away quite pure. The chloride of silver thus obtained was weighed after exsiccation.

A. The second quantity was treated with oxalate of ammonia while it continued to produce any effect. The precipitated oxalate of lime was washed, dried, and weighed.

B. To the remaining part of the solution nitrate of barytes was added till it ceased to produce any precipitate: and the sulphate of barytes obtained by its action ;

weighed, after washing and drying, as in the former experiments.

C. The residuum, insoluble in water, weighed, when dried, two grains; nitric acid added to it dissolved 1·7 grains. This solution afforded no precipitate with potash, but a copious one with oxalate of ammonia: it was therefore nitrate of lime obtained by the decomposition of the carbonate.

D. The 0·3 of a grain left by the nitric acid was dissolved by potash, and precipitated from it by chloride of ammonia. This precipitate was not again soluble in nitric acid, and was consequently silica.

Another quart of the water was treated in the same way. To avoid prolixity, I shall state the quantity of each precipitate afforded by one-third of a quart multiplied by three, and make the requisite calculation from the mean of the two experiments.

	Exp. I.	Exp. II.	Mean.
Residuum	30·	30·	30· grains.
Chloride of silver ...	16·2	16·2	16·2 ,,
Oxalate of lime ...	18·3	17·7	18· ,,
Sulphate of barytes	36·6	36·9	36·7 ,,
Carbonate of lime ...	1·7	1·5	1·6 ,,
Silica	0·3	0·4	0·35 ,,

According to Dr. Gibbes, a quart of the water affords nearly 4 grains of silica when treated in the method I have described. Thinking it probable that a portion of it might be taken up by the action of the salts during their solution in water, I tried whether any larger quantity could be obtained by the following method:—

E. A quart of the water was evaporated to dryness in a platina crucible. The residuum was repeatedly treated with nitric acid in a red heat; the soluble parts were again redissolved in distilled water, and the portion insoluble in it, when dried, weighed 0·4 of a grain. This agreeing exactly with the last experiment, I shall consider it as the quantity of silica afforded by a quart of the water. This experiment was several times repeated, with very little variation in the weight of the result, but was sometimes evidently coloured by oxide of iron, which was separated from the silica, and its nature ascertained by the usual means.

To find the quantity of oxide of iron contained in the water, the following means were employed:—

F. To a quantity of the hot water tincture of galls was added in the requisite proportion. The water measured when cold 9½ pints. The precipitate obtained was separated by the filter and dried. The precipitate and filter were then burned together in a platina crucible, and the carbonaceous matter of the filter, and that combined with the iron, were dissipated by the application of a red heat. The residuum was then treated with nitric acid, in order completely to oxidise the iron. It was then boiled with acetic acid to take up the lime precipitated with the oxide of iron by the tincture of galls: and afterwards with potash, to dissolve any silica which the filter might have furnished. The remaining substance was evidently peroxide of iron, and weighed 0·2 of a grain.

G. The last experiment was repeated, slightly varying the method. Tincture of galls was added, as before, to a quantity of the hot water, measuring after it had cooled 17½ pints. The precipitate was suffered to subside, and the water poured off until only a small quantity remained. This was evaporated, and the residuum, treated with nitric acid in a red heat, weighed 0·5 of a grain. Being exposed to a red heat with carbonaceous matter it became magnetic, and dissolved in hydrochloric acid, except $\frac{1}{10}$th of a grain, which appeared to be silica, derived from the water evaporated to obtain the precipitate formed by tincture of galls. The hydrochloric solution afforded a blue precipitate with prussiate of potash, 0·4 were therefore oxide of iron.

According to the experiment (*F*) one quart of the water affords ·0421 of a grain of oxide of iron, and by the second ·0463, giving a mean of ·0442; but the iron in the water is in the state of protoxide; and as the peroxide consists of 66·5 protoxide, and 7·5 oxygen, ·0442 will give ·0397, the quantity of protoxide of iron in one quart of the water.

16·2 of chloride of silver indicate 6·6 of common salt.

18 of oxalate of lime are produced by 18·6 of sulphate of lime.

18·6 of sulphate of lime afford 32 of sulphate of barytes, which subtracted from 36·7, the whole quantity of sulphate of barytes obtained, leave 4·7 for the sulphate of barytes formed by the sulphate of soda, equivalent to 2·8.

One quart of water therefore contains—

Carbonic acid gas	2·4 inches
Sulphate of lime	18·6 grains
Common salt	6·8 ,,
Sulphate of soda	2·8 ,,
Carbonate of lime	1·6 ,,
Silica	0·4 ,,
Oxide of iron	0·0397
	30·2397
Error	·2397
	30·

Estimating the sulphate of soda in the crystallised state, one pint of the water contains nearly as follows:—

Carbonic acid	1¼ inch
Sulphate of lime	9⅓ grains
Common salt...	3$\frac{4}{10}$
Sulphate of soda	3¼
Carbonate of lime	$\frac{8}{10}$
Silica	$\frac{2}{10}$
Oxide of iron...	$\frac{1}{50}$

SECTION 22.

Dr. Murray has lately published, in the 8th vol. of the "Transactions of the Royal Society of Edinburgh," a general formula for the analysis of mineral water, founded on the idea that the salts obtained from them by evaporation are not necessarily those which existed in the water, but that "the concentration by evaporation must in many cases change the state of combination, and that they may be frequently products of the operation, and not the original ingredients." He considers that the state of combination in which the component parts of salts, their acids and bases, may exist in a mineral water, may be contemplated under two views: first, that they may be in simultaneous combination, "the whole acids being neutralised by the whole bases;"—secondly, as constituting binary compounds, and that in this case the combinations are those which form the most soluble salts, their separation in less soluble compounds, on evaporation, arising from the influence of the force of cohesion. He proposes, therefore, to obtain separately all the acids and all the bases of the saline ingredients, and then to calculate from these data, the quantities of the respective salts they may be supposed to give rise to, considered as binary compounds of the greatest solubility, and existing independent of each other.

This method could hardly have been adopted a few years since from the very imperfect knowledge then possessed of the composition of the salts; but the great number of accurate analyses of those bodies which have since been made, and the establishment of the Atomic Theory, demonstr[illegible] constant and definite ratio of the combinations [illegible] have removed the difficulties that here-

The method proposed by Dr. Murray is as follows:—"Reduce the water by evaporation as far as can be done without occasioning any sensible precipitation or crystallisation; this, by the concentration, rendering the operation of the reagents to be employed more certain and complete. It also removes any free carbonic acid.

"Add to the water thus concentrated, a saturated solution of chloride of barytes, as long as any precipitate is produced, taking care to avoid adding an excess. By a previous experiment, let it be ascertained whether this precipitate effervesces or not with diluted hydrochloric acid, and whether it is entirely dissolved. If it is, the precipitate is of course carbonate of barytes, the weight of which when it is dried gives the quantity of carbonic acid: 100 grains containing 22 of acid. If it does not effervesce it is sulphate of barytes, the weight of which, in like manner, gives the quantity of sulphuric acid; 100 grains dried at a low red heat containing 34 of acid. If it effervesce and is partially dissolved, it consists both of carbonate and sulphate. To ascertain the proportions of these let the precipitate be dried at a heat a little inferior to redness, and weighed; then submit it to the action of diluted hydrochloric acid; after this wash it with water, and dry it by a similar heat; its weight will give the quantity of sulphate, and the loss of weight that of the carbonate of barytes.

"By this operation the carbonic and sulphuric acids are entirely removed, and the whole salts in the water are converted into chlorides. It remains, therefore, first to discover and estimate the quantities of the bases present, and then to complete the analysis, to find the quantity of hydrochloric acid originally contained. Add to the clear liquor a saturated solution of oxalate of ammonia as long as any turbid appearance is produced. The lime will be thrown down in the state of oxalate. This precipitate being washed, may be dried; but as it cannot be exposed to a red heat without decomposition, it can scarcely be brought to any uniform state of dryness with sufficient accuracy to admit of the quantity of lime being estimated from its weight. It is therefore to be calcined with a low red heat, by which it is converted into carbonate of lime, 100 grains of which are equivalent to 56 of lime. But as a portion of carbonic acid may be expelled, if the heat is raised too high, or a little water retained if it is not high enough, it is proper to convert it into sulphate by adding sulphuric acid in slight excess, and then exposing to a full red heat. The dry sulphate of lime will remain, 100 grains of which contain 41·5 of lime. The only source of error to which this step of the analysis is liable, is that which will arise if more barytes has been used in the first operation than was necessary to precipitate the sulphuric and carbonic acids. It will be thrown down in the state of oxalate of barytes, and be converted into carbonate and sulphate, and thus give the apparent proportion of lime too large. This is obviated, of course, by taking care to avoid using an excess of barytes. To render the operation of the oxalate of ammonia as perfect as possible in precipitating the lime, the water should be considerably reduced by evaporation, taking care to avoid any separation of any of its ingredients.

"The next step is to precipitate the magnesia; add to the clear liquor poured off after the precipitation of the oxalate of lime heated to 100°, and if necessary, reduced by evaporation, a solution of carbonate of ammonia; and immediately drop in a strong solution of phosphoric acid, or phosphate of ammonia, continuing this addition with fresh portions, if necessary, of carbonate of ammonia, so as to preserve an excess of ammonia in the liquor as long as any precipitation is produced. Let the precipitate be washed, when dried by a heat not exceeding 100°, it is the phosphate of ammonia and magnesia containing 0·19 of this earth; but it is better for the sake of accuracy, to convert it into phosphate of magnesia by calcination for an hour at a red heat: 100 grains then contain 40 of magnesia.

"Evaporate the liquor remaining after the preceding operations to dryness, and expose the dry mass to heat as long as any vapours exhale, raising it towards the end to redness. The residual matter is chloride of soda, 100 grains of which are equivalent to 53·3 of soda, and 46·7 of hydrochloric acid. It is not, however, to be considered necessarily as the quantity of chloride of soda contained in the water; for a portion of soda may have been present above that combined with hydrochloric acid, united, for example, with portions of sulphuric or carbonic acid. If with *carbonic* acid its alkaline properties must be evident in the recent water, at least when reduced by evaporation, by the test of turmeric paper, and from the nature of the analysis, this, in the progress of it, or rather in the first step, that of the removal of these acids by the chloride of barytes, would be combined with hydrochloric acid. It does not therefore give the original quantity of that acid, but it gives the quantity of *soda*, since no portion of this base has been abstracted, and none introduced.

"The quantity of hydrochloric acid may have been either greater or less than that in the chloride of soda obtained. If the quantity of soda existing in the water exceeded what the proportion of hydrochloric acid could neutralise, this excess of soda being combined with sulphuric or carbonic acid; then, in the removal of these acids by chloride of barytes, hydrochloric acid would be substituted, which would remain in the state of chloride of soda; and if the quantity considered as an original ingredient were estimated from the quantity of this salt obtained, it would be stated too high. Or if, on the other hand, more hydrochloric acid existed in the water than what the soda present could neutralise, the excess being combined with the other bases, lime or magnesia, then, as in the process by which these earths are precipitated, this portion of the acid would be combined with ammonia, and afterwards dissipated in the chloride of ammonia; if the original quantity were inferrèd from the weight of the chloride of soda obtained, it would be stated too low.

"To find the real quantity therefore, another step is necessary; estimate directly the quantity of hydrochloric acid in a given portion of the water, by abstracting any sulphuric or carbonic acid by nitrate of barytes, and then precipitating the hydrochloric acid by nitrate of silver or nitrate of lead. The real quantity will thus be determined with perfect precision, and the result will form a check on the other steps of the analysis, as it will lead to the detection of any error in the estimate of the other ingredients; for when the quantity is thus found, the quantities of these must bear that proportion to it which will correspond with the state of neutralisation.

"Thus, by these methods, the different acids and the different bases are discovered, and their quantities determined. And the results of the analysis may be stated in three modes:—1st, the quantities of the acids and bases. 2ndly. The quantities of the binary compounds as inferred from the principle, that the most soluble compounds are the ingredients, which will have at the same time the advantage of exhibiting the most active composition which can be assigned, and hence of best accounting for any medicinal powers the waters may possess. And 3rdly, the quantities of the binary compounds, such as they are obtained by evaporation, or any other direct analytic operation.

"With regard to other ingredients either not saline, or more rarely present, it will in general be preferable, when their presence has been indicated by the employment of tests, or by results occurring in the analysis itself, not to combine the investigation to discover them with the general process above described, but to operate on separate portions of the water, and to make the necessary allowance for their quantities in estimating the other ingredients. The quantity of iron, for example, in a given portion

of the water, may be found by the most appropriate method. Silica will also be discovered by the gelatinous consistence it gives on evaporation, and forming a residue insoluble in acids, but dissolved by a solution of potash. Alumina may be discovered in the preliminary application of tests, by the water giving a precipitate with carbonate of ammonia, which is not soluble, or is only partially soluble in weak distilled vinegar, but is dissolved by boiling in a solution of potash, or by its precipitation from the water sufficiently evaporated by succinate of soda; or in conducting the process itself, it will remain in solution after the precipitation of the lime by the oxalic acid, and be detected by the turbid appearance produced on the addition of the carbonate of ammonia previous to the addition of the phosphoric acid to discover the magnesia. Its quantity may then be estimated from its precipitation by carbonate of ammonia, or by other methods usually employed. Silica will also be precipitated in the same stage of the process; its separation from the alumina may be effected by submitting the precipitates, thoroughly dried, to the action of diluted sulphuric acid. Potash, when present, which is very seldom to be looked for, will remain at the end, in the state of chloride of potash. Chloride of platina will detect its presence, and the chloride of potash may be separated by crystallisation from the chloride of soda.

"There is another mode in which part of the analysis may be conducted, which although perhaps a little less accurate than that which forms the preceding formula, is simple and easy of execution, and may hence occasionally be admitted as a variation of the process; the outline of which, therefore, I may briefly state.

"The water being partially evaporated, and the sulphuric and carbonic acids, if they are present, being removed by the addition of chloride of barytes, and the conversion of the whole salts into chlorides effected in a manner already described; the liquor may be evaporated to dryness, avoiding an excess of heat, by which the chloride of magnesia, if present, might be decomposed; then add to the dry mass six times its weight of rectified alcohol (of the specific gravity of at least ·835) and agitate them occasionally during twenty-four hours, without applying heat. The chloride of lime and magnesia will thus be dissolved, while any chloride of soda will remain undissolved. To remove the former more completely, when the solution is poured off, add to the residue about twice its weight of the same alcohol, and allow them to stand for some hours, agitating frequently. And when this liquor is poured off, wash the undissolved matter with a small portion of alcohol, which add to the former liquors.

"Although chloride of soda by itself is insoluble, or nearly so, in alcohol of this strength, yet when submitted to its action along with chloride of lime or of magnesia, a little of it is dissolved. To guard against error from this therefore, evaporate or distil the alcoholic solution to dryness, and submit the dry mass, again, to the action of alcohol in smaller quantity than before; any chloride of soda which had been dissolved will now remain undissolved, and may be added to the other portion; or at least any quantity of it dissolved must be extremely minute. A slight trace of chloride of lime or of magnesia may adhere to the chloride of soda, but when a sufficient quantity of alcohol has been employed, the quantity is scarcely appreciable; and the opposite errors from these two circumstances counteract each other, and so far serve to give the result more nearly accurate.

"Evaporate the alcohol of the solution, or draw it off by distillation. To the solid matter add sulphuric acid, sufficient to expel the whole hydrochloric acid; and expose the residue to a heat approaching to redness, to remove any excess of sulphuric acid. By lixiviation with a small portion of water, the sulphate of magnesia will be dissolved, the sulphate of lime remaining undissolved, and the quantities of each, after exposure to a low red heat, will give the proportions of lime and magnesia. The quantity of soda will be found from the weight of the chloride of soda heated to redness; and the quantities of the acids will be determined in the same manner as in the general formula.

"This method is equally proper to discover other ingredients which are more rarely present in mineral waters. Thus alumina will remain in the state of sulphate of alumina along with the sulphate of magnesia, and may be detected by precipitation by bicarbonate of ammonia. Silica will remain with the chloride of soda after the action of the alcohol, and will be obtained on dissolving that salt in water. And iron will be discovered by the colour it will give to the concentrated liquors, or the dry residues, in one or other of the steps of the operation."

Dr. Murray obtains the quantity of gases a water may contain, by processes similar to those detailed in the preceding pages. M. Thenard remarks of Dr. Murray's method, that it is certainly good, but not in his opinion preferable to the one previously stated; which presents all the advantages of Dr. Murray's, since it equally enables us to obtain separately the quantities of the different acids and bases; and it is even more generally applicable to all cases.

Chlorine.

This is generally found in sewage, a thing which must, of course, be at all times kept clear of drinking water. The chlorine is produced from common salt, and the liquid excrement of animals, and I cannot do better than refer you to the tables of the Rivers' Pollution Commissioners, which from about 600 analyses the following is recorded:—

In 100,000 parts of rain water, ·22 parts; for upland surface water, in 100,000 parts, 1·13; for deep well water, per 100,000 parts, 5·11, which is very very strong in chlorine, and fully cent. per cent. more than I have found, excepting in very rare occurrences (but one thing should be noticed that they do not give what they consider the depth of a deep well. What is considered a deep well in the trade is nothing less than 60ft., the general impression being amongst us from 60ft. to 300ft. deep.) For spring water they say for 100,000 parts, 2·49.

Now this chlorine, which may come from cattle and other animals in small proportions, has many chances of getting into what we should term surface wells, which would naturally by the rain get washed out of the air and soil, and anything above 1 per cent. of chlorine in 100,000 parts of water should be rejected as suspicious; but when you get up to 5 per cent. you must be most carefully on the alert for sewage, or middens, or water closets, as human urine contains 500 parts of chlorine, or 824 parts of sodic chloride in 100,000 parts. These portions, you must quite understand, are only applicable to places away from the sea, and away from salt-bearing strata, and if close to the sea-side, little or no notice should be taken of this, except you have a strong suspicion of sewage, which may be easily discovered by looking for ammonia and other chemicals before referred to.

To determinate chlorine, place a hundred c.c. of the water into a flask, and stand it on a white sheet of paper. Then add a quarter of a centimetre of yellow potassic chromate (or a fifth of the chlorine test), drop by drop, until the liquor turns a faint red. The chromate of silver gives a deep orange red, which may be estimated accordingly, which, when tried a few times, you will be able to arrive at with great accuracy.

I should mention that chromate and chloride of silver are bo[illegible] [illegible]n water, and notice that you will not get [illegible] [illegible]manently formed until the last trace

of the chlorine is precipitated by the silver. By comparing tints of different strength-liquids in a second or third flask, the quantities will be easily obtainable.

Sea Water.

Sea water, which may be considered as a true mineral water, has been analysed by many chemists, whose experiments prove that the elements of the salts it contains are soda, lime and magnesia, and sulphuric and hydrochloric acids. These five substances by their combinations are capable of forming six salts, but it is not probable that they exist altogether in solution.

Be that as it may, the following are the results of the most recent analyses.

MM. Bouillon Lagrange, and Vogel, obtained from 100 parts of the sea water taken near Bayonne, in the Gulf of Gascony—

Sea salt	2·510
Hydrochlorate of magnesia	0·350
Sulphate of magnesia	0·578
Carbonates of lime and magnesia ...	0·020
Sulphate of lime	0·015
Carbonic acid	0·023
	3·496

Dr. Murray's analysis of the water of the Firth of Forth gave, in a hundred parts—

Lime	0·040	Sea salt	2·470
Magnesia ...	0·202	Hydrochlo. mag.	0·315
Soda	1·318 or	Sulph. of magnesia	0·212
Sulphuric acid ...	0·197	Sulph. of lime ...	0·097
Hydrochloric acid	1·337		3·094
	3·094		

Considering that the binary compounds formed in a dilute solution, must be those which are most soluble, he supposed the 100 parts of sea water analysed contain—

Sea salt	2·180
Hydrochlorate of magnesia	0·486
Hydrochlorate of lime	0·078
Sulphate of soda	0·350
	3·094

Dr. Murray also found carbonic acid in sea water, but he does not admit either carbonate of lime or carbonate of magnesia, because the precipitate by nitrate of baryta gave no effervescence with acids. He conceives the carbonates to arise from the decomposition of the hydrochlorates of lime and magnesia, in the process of evaporation to dryness.

Sulphur and Sulphurous Titles.

As the plumber is very much engaged in the manufacture of chemical plants for making sulphuric acid, sulphate of ammonia, sulphate of copper, and such like, doubtless if he is not fairly well up in chemistry, he, as I have seen many of my brethren, is a little fogged by the meaning of the different chemical terms, sometimes all of which he is apt to mix up as one and the same thing; and, as he probably thinks he is too much advanced in life to go in for a course of chemistry, the following will be useful at times:—

SULPHUR, when combined with oxygen, produces an acid.

Now this acid will be in two states of saturation, having different properties. To understand this it will be requisite to follow all the saline compounds of these two acids, and to pay particular attention to the sulphur in its direct combinations with earths, alkalies, and metals.

There are five terminations for distinguishing these five states of the same principal.

1st.—Sulphuric acid is sulphur in the utmost degree of saturation with oxygen. The purer the sulphur the better the sulphuric acid for lead burning purposes.

2nd.—Sulphurous acid is sulphur united with a smaller proportion of oxygen.

3rd.—Sulphate is the generic name of all the salts formed by sulphuric acid, such as sulphate of copper, sulphate of zinc, sulphate of ammonia, and so on.

4th.—Sulphite. This is the name of salts formed by the sulphurous acid.

5th.—Sulphuret. This is the name of all the combinations of sulphur not acidulous.

CARBON. When carbon is combined with oxygen it is known as carbonic acid, and consists of two of oxygen and one of carbon. When oxydised to form salts with bases of earth, metal or alkali, then it is known as carbonate of iron, or carbonate of potash, or carbonate of lime, and if combined with oxygen it becomes with iron, carburet of iron.

Salts are always distinguished by two names, denoting either the base or the acid, as follows:—

Sulphate of soda is a combination of sulphuric acid and soda; sulphate of iron is simply a compound like the former of sulphuric acid and iron; muriate of soda is a compound of muriatic acid and soda: and, notice this, that all salts composed of acids ending in *ous*, have the termination *ite*, instead of *ate*, as follows:—

Sulphur.
Sulphuric acid, a strong acid.
Sulphurous acid, a weak one.
Sulphuret of iron, sulphur and iron.
Prot-oxide of sulphur is the first degree.
Deut-oxide, the second degree.
Trit-oxide, the third degree.
Per-oxide, many degrees.
Sulph*ate* is the salt of sulphur*ic* acid.
Sulph*ite*, the salt of sulphur*ous* acid.
Bi-sulphate, the salt in double quantity.
Hypo-sulphurous acid—less oxygen than sulphurous acid (1 to 2.)
Hypo-sulphuric acid—less than sulphuric.

Analysis of Tin and Lead.

Introduce a certain quantity, say, 100 grains of the alloy into a matrass, add six or seven times its weight of pure nitric acid, of the specific gravity of 1·26, and expose it to a heat gradually raised. When the metallic particles have disappeared, and the acid ceases to give off nitrous gas, it must be evaporated to dryness, water poured on the residuum, and the whole thrown on a filter and washed, till the washings (which must be added to the filtered solution) no longer redden litmus, nor are blackened by sulphuretted hydrogen. The peroxide of tin remaining on the filter must then be dried and calcined, and deducting 21·4 per cent. for the oxygen, its weight gives the quantity of tin in the alloy.

Reduce the filtered liquor by evaporation, and precipitate by sulphate of soda; collect the sulphate of lead, wash, dry, and weigh it; one hundred of sulphate of lead contains 68·1 of lead.

Analysis of Plumbers' Solder.

Plumbers' solder, which contains two parts of lead and one part of tin, may be analysed like the preceding alloy; but if any copper be present, as is often the case, an additional operation is necessary. After the lead has been

separated, sub-carbonate of potassa or soda must be added to the solution to throw down the copper in the state of sub-carbonate, which a red heat will convert into oxide, from whose weight that of the metal is deducted.

Lead and Antimony, Analysis of.

As antimony is a favourite thing by unprincipled people to lighten plumbers' solder, the following analysis will be useful for detecting it.

This analysis for the antimony with lead may be made precisely as that of the alloy of tin and lead, deducting 26·5 per cent. for the oxygen of the deutoxide of antimony, but another analysis is required to separate the tin and antimony, in consequence of the antimony carrying a large quantity of oxide of tin down with it.

The proportion of antimony in the alloy must be pretty nearly ascertained by a previous experiment on five parts of the alloy, and one hundred of tin fused together, laminated and treated with hydrochloric acid; the undissolved portion will indicate pretty nearly the quantity of antimony. The alloy is then fused with such a portion of tin that this metal may be to the former as 20 to 1, including the tin in the alloy. The addition of the tin must be made with some care that the combination of the metals may be perfect. M. Chaudet places them wrapped in paper in a small crucible, covers them with charcoal powder, and fuses them under the muffle of a cupelling furnace. The button when cold is cleaned and laminated, cut into pieces, and fused again as before; and this operation is repeated a third time, but without laminating the button, with a piece of paper placed between the metal and the charcoal powder, the button may be perfectly homogeneous.

The new alloy is then to be rolled into a thin plate, cut into pieces, and boiled in a flask, with an excess of pure hydrochloric acid of the specific gravity of 1·19 for two hours and a half at least. The whole of the tin will be dissolved, but the antimony remains untouched. The solution is then to be diluted with distilled water, and the insoluble matter collected on a filter; its weight will be exactly that of the antimony in the alloy. The lead contained in the alloy must be laminated with great care, as that metal adds extremely to its brittleness. The quantity of lead may be ascertained by treating a portion of the alloy with nitric acid, and precipitating the lead by sulphuric acid.

You can also analyse an alloy of tin and bismuth in the same manner, but in this case it is better to use nitric acid, which dissolves the bismuth and leaves the tin.

Solder (Plumbers') and Zinc.

Burning Zinc out of Plumbers' Solder.

[illegible] suspect the presence of zinc to be in your [illegible] will cause it to work short or brittle, it may [illegible] by first throwing a little sulphur in, [illegible] same well up. Then with some red hot [illegible] on the top, sufficient to well cover it, and [illegible] for a quarter of an hour or so. The [illegible] zinc whilst the red hot coals [illegible] you think it is all right, and [illegible] skim the pot and let it [illegible] candle to every [illegible] it gets too cold, [illegible] good quality,

[illegible]

Next redissolve this by the potassic iodide you put aside, and then with *great care* add more solution of mercuric chloride till after stirring a slight precipitate remains.

Now add to this made liquid 150 grams of potassic hydrate dissolved in sufficient distilled water to make the whole up to one litre, which must be allowed to settle. Then decant off all the clear yellow liquid into a suitable bottle, with a good ground-in glass stopper, when it is ready for use at any time. N.B.—I have some which is in first-class order made by Mr. Feltwell, of Hammersmith Road, so long back as the year 1879, which I would not take any money for, it being so very sensitive.

Ammonia Chloride Test.

This standard solution is made by dissolving 1·5735 gram of pure dry ammonic chloride in one litre of distilled water.

Dilute 1 c.c. of this strong solution to one litre. You will then have 1 c.c. = in strength of ·00005 gram NH_3.

Sodic Carbonate Test.

For an hour or so strongly heat to dry (but not to fuse it) the carbonate, and preserve it in a suitable small but wide-mouthed bottle, having a ground-in stopper.

Water without Ammonia.

To prove this, known distilled water should be again distilled (but good water may be employed) with sodic carbonate; but reject the distillate till it ceases to react with Nessler test; but stop the distillation when the retort liquid is reduced to one-sixth of its original bulk.

Nitrates and Nitrites Test.

Sodic Hydrate.—Solution of sodic hydrate 10 per cent., freed from nitrates by dissolving 100 sq. c.m. of aluminium foil in a litre, and then well and sharply boil the liquid in a porcelain basin to evaporate one-third, then make up the original quantity with *pure* distilled water.

Pumice Test.

Take some pieces ½in. or so square, and heat the same for an hour or so, and put them into a glass stoppered bottle.

Hydrochloric Acid Test.

Should there be any ammonia, say three drops, this must be rectified from sulphuric acid.

Estimation of Chlorine Test.

Silver solution. Dissolve 2·3944 grams of argentic nitrate in one litre of pure water. This should be measured out in a burette divided into tenths of a c.c.

Potassic Chromate Solution.

From a dropping tube deliver a strong solution of pure neutral chromate free from chlorine.

Standard Soap Solution.

This solution should be made a little too strong, and allowed to stand a day or two before using. Take 40 parts of dry potassic carbonate and 150 of lead plaster (Emplastrum Plumbi, B.P.), and well mix in a pounding basin or mortar. Stir this thoroughly with methylated spirit, and set it aside for about ten hours; filter and wash with more methylated spirit. You can tell the strength by adding 50 c.c. of the calcic chloride solution; go about this as though determining hardness. With alcohol and water dilute till [illegible] 14·25 c.c. are required to make a [illegible]

permanent lather with 50 c.c. of solution of calcic chloride.

Add the water in such quantities as to make a proportion of water to the spirit as one is to two.

Water Samples (*Collection of*).

The tedious and troublesome operation of analysing water should warrant you in being most careful in collecting the samples.

Do not take only that which is fair and square, which I have known unprincipled people to do, when the water of a well or spring has been in question, for if you do, most likely you will get dropped on from another analyst, when it may be necessary to call in a third, and the expense of the lot fall upon you or your client.

Take six *new* Winchester quart bottles with ground-in stoppers. Take two of them as they are to the water, and from half to three parts fill them, by dipping the bottle into the water, so that you cannot get the water from the surface, nor from the bottom. Thoroughly wash the bottles; then fill them to within, say, 1in. of the stopper. With some clean washed wash leather, or calico, tie the stoppers down, and seal the strings. Next write two labels with the name of the spring, well, or wherever you get the water from. Set down the hour and day of the month when collected, and by whom witnessed. Place the bottles in a cool, dark place, and be careful not to expose them to the light.

For three successive days do this, but at different hours; say the first is taken at 9 a.m., next mid-day, next 3 p.m., and label accordingly. Send three samples to the analyst (have a good one, Professor Franklin, of The Yews, Reigate, is excellent), and retain three yourself, or, better, deposit these three bottles into safe keeping in case of dispute.

Should the water be company's water, call in the company, and let them know what you are up to, and be sure to take the samples direct off the supply, or, properly speaking, the communication pipe, but not before a few gallons have run to waste, so that you get water without lead or undue iron.

Should it be pump-water, then work as before, but keep the pump going for three or four minutes before the sample is taken direct into the bottles, and should it be a landlord's pump, invite him to witness the operation. Remember this, that everything connected with this operation must be scrupulously clean, and if from a draw well, see that the chain, wire, or rope is not rusty or dirty.

When sending in water to the analyst, say what you expect, as follows:—

Sewage.

Chemical works pollution.

Gasworks.

Tin, copper, lead, &c.

Describe the distance of well from cesspool drain, or farmyard.

Depth and diameter of well.

Class of pump.

Soil, and sub-soil, and the stratum into which the well is sunk, and what water you expect it to be, and the fluctuation in the depth of the water, winter and summer.

If from streams or rivers, state the head or source, and the distance; and if the stream runs through much wooded land, or if other sources empty therein.

Also state if you know anything as to whether animals can walk through or into the stream. This is very important for the ammonia, cow dung, &c.

The stratum from which the spring issues.

State whether you have taken the water direct or indirect from the spring, and if the latter, try and also get a sample from the head, though this may cause double expense.

It is only fair to say that you must not on any account expect to arrive at satisfactory results until you have had some *years* of practice in this department.

But if you are ingeniously inclined this is the most interesting of all sciences to fill up your spare evenings and odd time, because you can find something fresh at all times. If you do go at it, go at it with a will, and it will then repay you, though not from a monetary point of view, for it comes very expensive, especially by the time you have bought a good microscope, chemical balance, and a few more indispensables. It will be all the better if you can get a good old grand-dad to purchase these for you, as they generally have some cash to spare just before quitting for the next world, and he will be especially generous if you tell him that with the microscope, *if a good one* (about a £75 one, for a duffer is a trouble), you will be able to tell him all about the devils, not only that has plagued him in this world but in the world to come. And it is astonishing how benevolent he will be (*especially if you know all about it at once*), and he will call you such a very clever and most *promising* young man.

Now, you having just began to feel interested in this part of the work, pull away at the old methods which I have given. Then send to Messrs. Spon, my publishers, for Dr. Lancaster's, also George E. Davis, C.E., &c., &c., also Carpenter's work on the microscope, Roscoe's "Chemistry," Professor Frankland's "Water Analysis," also Percy Frankland's book, and also Gosse's works on "Micro-Organisms in Water," and you will want nothing more but a few tools and *practice* to know all about water, especially if you tumble in head first.

Micro-Organisms, and Sanitary Science.

(*Also see Microbes and Fever Bacillus, and also Stinking Water.*)

I have before spoken of microbes, or fever-cholera bacillus (see heading), and how they affect the animal kingdom. I have also said that these devils come from seas and up our rivers, also that they can be filtered out by proper filtration. I will, therefore, now show you a little more about them.

Fig. 959J is an engraving of microbes, &c., I have arranged for this work.

FIG. 959J.

L, Fig. 959J, is the cyclops quadricornis.

This active creature creates with its feet-jaws a whirlpool in the surrounding water, which draws minute animals, and even its own young, to its mouth to be devoured.

M, are the lares. These are about $\frac{1}{40}$th of an inch long, having arms and a head resembling the human figure, which they throw about in a most extraordinary manner, as if to mimic the actions of the most tumultuous human passion.

K, is the grub of the chameleon-fly. This inhabitant of the water may be seen with the naked eye. Its peculiarity is the last joint of its tail, which is tipped with a beautiful crown of feathers, like the diadem of a semi-savage prince, which is best seen when the chameleon grub comes to the surface, always tail uppermost, and the moment the tip reaches the air, its plumes instantly open into a kind of cone or funnel, from which all moisture is instantly excluded. The water then stands perfectly level with the brim. The animal then remains stationary, head downwards, then suddenly the tips of the plume curve inwards towards each other, embracing a globule of air, and away the creature wriggles into the depths, with its load of air glittering behind it. If you wish to see it through a glass, use one from 35 to 50 diameters.

N. The vibrio rugula are in the act of separating from each other, and drawing out a protoplasmic filament to form their second flagella. This is magnified to 2,000 diameters.

I. The euglena viridis. This is often found in prodigious numbers, which gives the water a green pea soup colour. Its general appearance under the microscope is that of a red speck or point, with an elongated kind of tail at the other. This red spot is supposed to be the eye, but, if carefully watched, you will find this spot to extend over the rest of the body.

B. These are some of the more typical forms of micro-organisms, as seen under the microscope. Monococcus, which is pathogenic to man, dogs, horses, sheep, fowls, rabbits, &c. They cause swellings and ulcers. They are magnified 650 times.

E. Ciliated cell., magnified 500 times.

D. Spider cell. or spirillum or Asiatic cholera bacillus, magnified 700 times. See cholera bacillus.

A. The typhoid bacillus surrounded by the flagella or locomotion organs. This creature is magnified 1,100 times. See description of typhoid bacillus.

F. G. H. This is bacillus subtilis or hay bacillus. It is not pathogenic, and is found in hay infusions, water, air, fæces, and putrid liquids. It is 6 μ long, and one-third its length broad, and grows into long threads.

C. This is fusisporium moschatum, magnified 300 times. This is found in water, forming large greenish white slimy masses, hanging down like so many rags from the outlet of cocks, sometimes having a pale pink and brownish colour. It is also found on turbines and water wheels, and gets between the wheels of the mill. They average from 6 to 14 μ long, to 1 or $1\frac{1}{2}$ μ broad. If these spores are dried and preserved, they will, after four or five months lying by, still grow. They are pathogenic, even to frogs, and, when smashed, give an intensely strong aromatic smell, which will produce headache if inhaled, the odour being of a musty production.

It is within my recollection that these microbes have been brought by sanitarians and other scientists prominently before the water drinker's notice, and it is a subject which should be well thought over by every one professing to be water caterers, or by those having to do with the supply of water, whether it be by a common draw-well, spring, pump, or river, and no one should allow himself to draw upon his imagination that he has the slightest right to warrant him in classing himself as a sanitary engineer until he knows right well all about the breeding, cultivating, and killing of micro or bacillus germs.

Liebig tried to explain all about fermentation, and dead yeast undergoing decomposition. He told us that which his grandfathers' knew, that our waters were contaminated simply by decomposition of vegetable and animal substances. That by our drinking thereof, we, in turn, would soon become putrefactive bodies, &c., which dogma was broken down by the just lamented late M. Pasteur, who proved that the process of fermentation was caused by the *living* organisms, which were the cause of all zymotic diseases. Pasteur, we may say, gave us a push off the diving plank into a wide sea, full of living organisms. He opened the eyes of the medical men, and told the sanitary engineers as to what zymotic diseases undoubtedly are, and plainly showed how Asiatic cholera and typhoid fever are to be communicated.

At first there was a certain amount of empiricism about it; but, since this, we have accepted the germ theory of disease, and thus, by working away, our water bacterial and hygienic knowledge has spread throughout the land, and now established the A, B, C of sanitary science.

Then we have Doctor Koch. He has given a good helping hand by the publication of his work on Bacteriological Science, and much improved the aspect of water supply and sanitary knowledge.

Then we have two others, who are second to none in this department. First we will take E. Frankland, whose work is well up to date in the chemical portion. Then there is Percy Frankland, whose work on Micro-Organisms is not to be outdone, and a work which should be in the hands of every student and *master* bacteriologist.

Now, so far as regards these bacillus microbes, these are the minute devils I cannot tolerate. Some would say—"They must come in the air?" Yes; they float in the air, and they come from, and cause putrefied vegetable and animal matter. They get into the water, and even the rain cannot fall in some parts without being contaminated with them, especially on all soils where plants grow, and on which animal life exists. Were it not for these devils our milk would not go sour, eggs would remain fresh, meat would not become tainted, bread remain sweet and without mouldiness; animals and vegetables would simply dry up and not stink.

Micro Germs and their Names.

Most of our drinking water contains a large army of microbes, which fight other germs till death, which otherwise we may swallow alive; and I have heard it said by some that these devils are useful to health. But I am not the one to say those who conquer we should protect, but give me the water which is free from any one class of these devils.

One, bacillus subtilis, is found in the stomachs and intestines of oxen and other herbivorous animals, and is by some people believed to assist in digesting their food. There is also the bacillus *coli* communis, as uniformly exists in human beings, performing an analogous office. But what about bacillus anthracis? This is found in sheep; it is also found amongst wool sorters, which brings up large lumps on the face and other parts of the body. Pasteur obtained these devils in broth. These devils are also found in sediments in the bottom of wells.

I do not know how deep these devils go, but know that the Kent Water Works wells get very few. I also know that you do not find them in the air of mountainous districts, say 2,000 feet in height.

Koch's comma spirillum. This is the devil of the Asiatic cholera, which is found in the dejecta of cholera patients, and in the fresh intestinal contents of cholera corpse, and comes in air and *water*. This is of a very peculiar and dangerous kind. It seems to cling together, and forms itself into a kind of semi-circle, after the style of the consonant S, the two ends having three or more threads in the shape of a corkscrew. This devil is very motile.

The general sympt[illegible] this disease are as follows:—

A general feeling [illegible]s, chills and coldness which

give a shivering effect, pains in the bowels with rumbling sounds, oppression, and anxiety about the stomach, with severe purging sometimes accompanied with vomiting, at other times great thirst, with the pulse small and weak; inactivity, yellowish skin or eyes, bitter taste in the mouth and dislike of food, fulness at the pit of the stomach together with pressure, cramp and rumbling. When such is the case, and cholera suspected, you should lose no time in going to a medical man. Camphor is good to carry about with you in cholera seasons.

Typhus or Typhoid Bacillus.

(*Bacillus Typhi Abdominalis.*)

This is found in the blood, fæces and urine, and other products of the human organs, and, as its name implies, always in typhoid patients.

This devil is also found in air and water. It is a short plump kind of bacillus, rounded at the ends, and three times as long as it is broad, generally found without company in the tissues. It is motile, and has attached to both sides and ends numerous cilia, and grows abundantly in milk.

These devils appear to be of various grades, and produce what is called, when in its mildest form, typhoid fever, which is a slow or nervous fever, which may go on increasing till it becomes malignant, when its true and general application is typhus, which brings on debility with a tendency of the fluids to putrefaction. It is distinguished from other fevers by the weakness of the pulse and great prostration of strength, and brings with it pains in the head, back and limbs; heat and dryness of the skin; extreme mental and bodily depression; thirst, constipation, and delirium. But enough of this, or I shall be very soon brought in as a quack doctor, to which I have no pretensions.

Bacterium Lactis Aërogenes.—This is found in the intestinal tract of animals, and of people fed with milk, and therefore children are especially liable to be infested with these germs. In cases of pneumaturia, the urine is attacked. This is one of the devils which is the cause of typhoid fever. They are found in pairs, generally side by side; they also group together in irregular heaps. Their shape is somewhat like short rods, and very plump.

Proteus Vulgaris.—This is a kind of slightly bent bacillus, something of a snake-like thread; very motile, and has long cilia. It is found in putrefying animal substances, also in urine, and gives off a sickening odour of putrefaction.

Bacterium Tholœideum is found in water, causing typhoid fever, also in the intestinal tract of healthy people. It is also found in blood.

Bacillus Proteus Fluorescens.—This is found in streams of water containing dead carcases, and gives an infectious feverish icterus to people who bathe in such contaminated water. It is also found in fowls suffering from disease. The general appearance is somewhat short and thick, rounded at the ends; they mostly go in pairs, and are provided with numerous cilia. They are also motile.

Bacillus of Mouse Septicæmia.—This is found in drain water. It resembles a small whitish cloud, not motile, and occurs in pairs.

Bacillus Brevis.—This is also found in drain water, something after the above.

Bacillus Capsulatus is also found in drain water. This bacillus is of a rod-like form, somewhat elliptical, and is at times found joined end to end enclosed in a capsule, not motile.

Bacillus of Tetanus.—This is found in air, water, and in pus from tetanus wounds. This is a kind of straight bacillus with its ends rounded, and occurs in long threads and sometimes singly. It has been found fatal to horses, sheep, and dogs.

Proteus Mirabilis.—This is found in putrefying animal substances.

Proteus Zenkeri.—This is also found in putrefying animal substances, and amongst organisms found in water.

Bacillus Saprogenes.—This is found in the perspiration from feet, and if inoculated into the knees and pleural cavities of rabbits, the purulent inflammation will cause the animals to die.

Bacillus Cloacæ.—This is found in sewage, perhaps the most common bacillus in such matter. It is of a short, plump, oval shape with rounded ends, very motile, and frequently found in pairs.

Micrococcus Biskra.—This is found in air and water; also in pus and serous exudations. The general appearance is that it is covered with a capsule, and when lying side by side have the appearance of sarsenet.

Vegetable matter when in a state of decomposition is not generally credited with, as is the case, being swarmed with bacilli, having rod-like forms of various dimensions, which are found in nearly every pond and open stream, and although they produce decomposition, give to that water no odour.

There are microbes of ordinary decomposition which, if allowed to get down one's throat in too large numbers to be destroyed by the secretions of the digestive organs, cause the food to decompose in the stomach or in the bowels (before reaching they would have a longer time to multiply), and in so doing would produce acute diarrhœa, and other digestive disturbances; and especially so should one be exposed to heat, and then cold, or if the food be of an indigestible character.

Other microbes exist that possess a power of altering matter which no longer lives, but still remains in the living tissues of human beings and other animals, and ultimately cause the breaking up of the microscopic structure of the tissues, poisoning and rendering them incapable of discharging the functions of life.

These require no explanation from me; suffice it to say, they are known as disease germs, such as the *micrococcus* or *bacterium* of small-pox, the bacilli of typhoid fever, of diphtheria, of glanders, and the spirillum of Asiatic cholera, and also of consumption.

These devils, as I have also in other parts of my writings referred to, pass directly from one individual to another of the species which they affect. They appear to be races, originally engendered by the ordinary microbes of decomposition, which appear to adapt themselves to special conditions, but when mingled for any length of time with the microbes of decomposition, will be killed off, especially if exposed to light and air.

Light and air appear to be detrimental to the microbes of ordinary vegetable and animal decomposition, which die off when there is nothing more to live upon, by such matter becoming oxidised.

It is also a fact that there are more microbes in flood-ver-sterile water seasons, which is one reason why water should never be taken into a reservoir during flood times.

Rapid running streams (here I bar flood seasons) destroy zymotic matters of a pathogenic kind, or, at least, so much so, that the most minute microscopic inspection of the water has failed to discover a single pathogenic germ.

Bacterial Standard Purity of Water.

A hundred microbes per cubic centimetre is, in Londo[illegible] considered to be the recognised test of practical bac[illegible] purity of the water.

It must be remembered that there are various w[illegible] communicating these organisms to different subst[illegible] Some will say that they come from bad air, sewage, d[illegible] ing water, and for the want of drinking water, and

down in a very arbitrary manner, that nearly all infectious diseases of the zymotic kind come from a scarcity of water, and I have known many medical officers prejudiced in this matter, who, I unhesitatingly say, without the slightest legitimate reason, pick out shortness of water, or water stored in cisterns generally, as the cause of zymotic diseases, and they have boldly asserted that these zymotic diseases have put up the death rate to an alarming extent in the very same week and beginning with the *same day*, that the East London Water Works Company failed to satisfy a few of their consumers for this particular day—and notice this day and week—when they happened to be on the constant supply. Whereas another medical man of equal standing proved that the water supply had nothing whatever to do with the infectious disease. How could they possibly have fever in this particular spot, owing to a few hours, not six hours' shortness, the same day that the water supply was reduced to three hours, instead of being on twenty-four hours?

This diarrhœal disease happened at the time to be very prevalent in London. These complaints were seasonal, and mainly occasioned by high temperature, and London compared favourably with the provinces and in large towns where a constant water supply was given.

Speaking of these zymotic diseases one thing is certain, that during the early part of this summer we had tremendous storms—though the water does not always get direct into our rivers, owing to percolation, as was the case with shortness of water this year, with the River Thames and Lea—the weather has also been excessively hot, and when such is the case the bacterial germs are always prevalent in the air. They are brought down in our rain water, and so deposited, and as is well known, thrive more in poor populated or confined neighbourhoods than in neighbourhoods of the rich and more open or spacious parts, where the germs become more readily oxidised. Here is another way whereby the poorer class of people suffer from these fatal falling organisms.

People of the lower working class are naturally compelled to be out in these zymotic storms. Their clothing often becomes saturated; the clothing being of a vegetable kind, is a breeding place for these germs, and the heat of the body is most favourable for their propagation. These poor people, *especially children*, take cold, when these germs have every opportunity to infest, according to their particular class, the internal parts of the body, and this is the reason why this particular rise in the death rate took place.

Of course, I am in favour of plenty of water at all times, but how is this to be maintained? Simply by ample storage.

Divisibility of Microbes and Chemicals.

This work will not allow me, for want of space, to teach you a twentieth part of what I could about micro-organisms, chemicals, and such like. Therefore, I recommend you to well study the works I have already named, and I shall conclude this portion of the work by showing how to arrive at counting of microbes, and ascertaining strengths of different chemicals, which is easily done if sufficient care be used, though at first sight this may seem an alarming task to count 100,000 microbes in half a cubic inch of water, many of which are not the millionth part of an inch long. But nothing is wonderful except to the ignorant, because, scientific wonders are, like everything else, built upon minute facts or principles.

We will take one c.c., which is taken at twenty drops of water, and say it is contaminated with 10,000 microbes. Now take these 10,000 microbes, and put them into 100 c.c. of absolutely pure water, and divide these 100 c.c. into ten absolutely pure sterilised test tubes (I should here remark that sterilisation signifies in this bacterial work baking of the tubes in an apparatus, which may be had from Messrs. Griffin & Sons, or any bacteriological instrument maker), when each test tube will contain 500 microbes. Now take one of these test tubes containing the 500 microbes, and in the same way dilute this test tube liquor with 100 parts of pure water, and divide this again with your test tubes, which will bring your microbes down to a minimum, according as you choose to work, some working one way and some another. The liquor at last being brought to a centimetre, a portion of this liquor can be brought under a counting frame, known as Wolffhügels', which can be had from any bacteriological instrument maker.

This is quite sufficient to give you a general insight as to the counting, and for the further process, of course, you must seek the works I have already named, which are nearly quarter the size of this work itself.

Chemical calculations and assaying are carried out in a similar manner, often by dilution, whilst at other times by distillation.

Useful Hints and Facts—*continued.*

1 cwt. water = 11·2 imperial galls.
1 litre of water = ·22 imperial gall.
1 litre of water = 61·028028 cubic inches.
1 litre of water = ·0353 cubic foot.
1 cubic metre of water = 222 imperial galls.
1 cubic metre of water = 1·308 cubic yard.
1 cubic metre of water = 61028 cubic inches.
1 cubic metre of water = 35·31 cubic feet.
1 cubic metre of water = 20 cwts. approximately.
A column of water 1 metre high = 1·43 lb. per square inch.
A cubic inch of zinc or cast iron weighs 4·16 ozs.
A cubic inch of copper, 5 ozs.
A cubic inch of silver, 6 ozs.
A cubic inch of lead, 6½ ozs.
A cubic inch of gold, 10⅕ ozs.
A cubic inch of platinum, 11·285 ozs.

English Long Measure.

This is taken from the pendulum, 39·1393 inches at London, which vibrates seconds; and one mile of 1,760 yards is equal to 1618·833 such pendulums.

An inch is ·02555 of the pendulum.

The smallest measure we have is a hair's breadth of 48 to an inch. (Caution.—There are many more than 48 human hairs to the inch.) I have just measured a lady's and also a man's hair, and found it to be $\frac{8}{100}$ part of a millimetre.

An inch is divided into 12 lines, by the plumber, into eighths.

In decimal divisions the eighth of an inch is ·0125, and an inch is the 0·0833 of a foot.

A fathom is 6 feet, taken from a 6ft. man wading.

A mile is 1,760 yards (English).

Weights and Measures used in Volumetric Analysis, &c.

At the present time three different units of measurement are in use amongst English chemists.

The first is the centimetre cube, called cubic centimetre (c.c.); about 20 drops of water or 1,000 c.c. to a litre.

The second is the decem., or the measure of 10 English grains of water at 62° Fahr.

The third is the septem., which contains 7 English grains of water at 62° Fahr.

The above two measures are used in conjunction with a vessel marked to hold 1,000 of each of these measures as in the litre above.

There is an Act of Parliament rendering permissive the use of the metric system of weights and measures.

The kilogram is said to be equivalent to 15432·3487 British grains.

The litre to be equivalent to 1·076077 British [illegible] the litre = to 0·567932 of a British imperi[illegible]

The number of cubic inches in a pint is 34·65925, or 277·274 cubic inches per gallon.

The number of grains in a pound is 7,000, and the number of grains of water in a pint is 8,750.

If you therefore deduce the following equivalents:—

15432·3487 ÷ 7,000 = 2·20462125 imperial pounds in a kilogram.

1·76077 × 8,750 = 15406·7375 grains of water in a litre.

15406·7375 ÷ 7,000 = 2·2009625 pounds of water in a litre.

A gramme (or gram, as it is spelt in the Act of Parliament) is the 1,000th part of a kilogram, and a c.c. is the 1,000th part of a litre.

A gram weighs against metals 15·4323487 English grains.

A cubic centimetre of water contains 15·4067375 English grains; or a difference between metal and water of 0·0256112 English grain.

A cubic foot of water = 62·321 lbs. of water, or 997·137 ounces, usually taken as 1,000 ounces.

A hogshead is 54 imperial gallons of beer measure, also water; or 540 lbs., plus the cask.

P. J. DAVIES'S LEAD PIPE AND HOT WATER CYLINDERS, OR PUMPS, TABLE *(Registered).*

With Diameters, Circumferences, Areas, and Volume Displacements in Gallons per foot of Travel up to 50in.

LIQUID AND OTHER MEASURES. *(See also Useful Hints and Facts, page 443.)*

Diameter of Pipe.	Circumference.	Area. — Square Inches.	Displacement in Imperial Gallons per Foot of Travel.	Diameter of Pipe	Circumference.	Area. — Square Inches.	Displacement in Imperial Gallons per foot of Travel.	Diameter of Pipe.	Circumference.	Area. — Square Inches.
1/16 inch	·196	·003	—	11½ inches	36·12	103·86	4·484	52 inches	163·36	2123·72
⅛ ,,	·392	·012	·0005	12 ,,	37·69	113·09	4·881	53 ,,	166·50	2206·18
¼ ,,	·785	·049	·0021	12½ ,,	39·27	122·71	5·300	54 ,,	169·64	2290·22
⅜ ,,	1·178	·110	·0047	13 ,,	40·84	132·73	5·732	55 ,,	172·78	2375·83
½ ,,	1·570	·196	·0084	13½ ,,	42·41	143·13	6·182	56 ,,	175·92	2463·01
⅝ ,,	1·963	·306	·0132	14 ,,	43·98	153·93	6·649	57 ,,	179·07	2551·76
¾ ,,	2·356	·441	·0190	14½ ,,	45·55	165·13	7·132	58 ,,	182·21	2642·08
⅞ ,,	2·748	·601	·0259	15 ,,	47·12	176·71	7·633	59 ,,	185·35	2733·97
1 ,,	3·141	·7854	·0339	15½ ,,	48·69	188·69	8·147	60 ,,	188·49	2827·44
1⅛ ,,	3·534	·994	·0429	16 ,,	50·26	201·06	8·683	61 ,,	191·63	2922·47
1¼ ,,	3·927	1·227	·0530	16½ ,,	51·83	213·82	9·236	62 ,,	194·77	3019·07
1⅜ ,,	4·319	1·484	·0641	17 ,,	53·40	226·98	9·802	63 ,,	197·92	3117·25
1½ ,,	4·712	1·767	·0763	17½ ,,	54·97	240·52	10·389	64 ,,	201·06	3216·99
1⅝ ,,	5·105	2·073	·0895	18 ,,	56·54	254·46	10·990	65 ,,	204·20	3318·31
1¾ ,,	5·497	2·405	·1038	18½ ,,	58·11	268·80	11·612	66 ,,	207·34	3421·20
1⅞ ,,	5·890	2·761	·1192	19 ,,	59·69	283·52	12·247	67 ,,	210·48	3525·66
2 ,,	6·283	3·141	·1356	19½ ,,	61·26	298·64	12·900	68 ,,	213·62	3631·68
2⅛ ,,	6·675	3·546	·1531	20 ,,	62·83	314·18	13·569	69 ,,	216·77	3729·28
2¼ ,,	7·068	3·976	·1717	21 ,,	65·97	346·36	14·960	70 ,,	219·91	3848·46
2⅜ ,,	7·461	4·430	·1913	22 ,,	69·11	380·13	16·420	71 ,,	223·05	3959·20
2½ ,,	7·854	4·908	·2120	23 ,,	72·25	415·47	17·945	72 ,,	226·19	4071·51
2⅝ ,,	8·246	5·411	·2337	24 ,,	75·39	452·39	19·539	73 ,,	229·33	4185·39
2¾ ,,	8·639	5·939	·2565	25 ,,	78·54	490·87	21·202	74 ,,	232·47	4300·85
2⅞ ,,	9·032	6·491	·2804	26 ,,	81·68	530·93	22·935	75 ,,	235·62	4417·87
3 ,,	9·424	7·068	·3053	27 ,,	84·82	572·55	24·732	76 ,,	238·76	4536·47
3¼ ,,	10·210	8·295	·3583	28 ,,	87·96	615·75	26·598	77 ,,	241·90	4656·63
3½ ,,	10·995	9·621	·4156	29 ,,	91·10	660·52	28·533	78 ,,	245·04	4778·37
3¾ ,,	11·781	11·044	·4769	30 ,,	94·24	706·86	30·533	79 ,,	248·18	4901·68
4 ,,	12·566	12·566	·5426	31 ,,	97·38	754·76	32·607	80 ,,	251·32	5026·50
4¼ ,,	13·351	14·186	·6125	32 ,,	100·53	804·24	34·741	81 ,,	254·46	6153·00
4½ ,,	14·137	15·904	·6868	33 ,,	103·67	855·30	36·949	82 ,,	257·61	5281·02
4¾ ,,	14·922	17·720	·7655	34 ,,	106·81	907·92	39·221	83 ,,	260·75	5410·62
5 ,,	15·708	19·635	·8480	35 ,,	109·95	962·11	41·562	84 ,,	263·89	5541·78
5¼ ,,	16·493	21·647	·9348	36 ,,	113·09	1017·87	43·973	85 ,,	267·03	5674·51
5½ ,,	17·278	23·758	1·026	37 ,,	116·23	1075·21	46·448	86 ,,	270·17	5808·81
5¾ ,,	18·064	25·967	1·121	38 ,,	119·38	1134·11	48·993	87 ,,	273·31	5944·69
6 ,,	18·849	28·274	1·221	39 ,,	122·52	1194·59	51·607	88 ,,	276·46	6082·13
6¼ ,,	19·635	30·679	1·325	40 ,,	125·66	1256·64	54·256	89 ,,	279·60	6221·15
6½ ,,	20·420	33·183	1·433	41 ,,	128·80	1320·25	57·037	90 ,,	282·74	6361·74
6¾ ,,	21·205	35·784	1·545	42 ,,	131·94	1385·44	59·849	91 ,,	285·88	6503·89
7 ,,	21·991	38·484	1·662	43 ,,	135·08	1452·20	62·735	92 ,,	289·02	6647·62
7½ ,,	23·562	44·178	1·908	44 ,,	138·23	1520·53	65·686	93 ,,	292·16	6792·92
8 ,,	25·132	50·265	2·171	45 ,,	141·37	1590·43	68·688	94 ,,	295·31	6939·79
8½ ,,	26·703	56·745	2·451	46 ,,	144·51	1661·90	71·794	95 ,,	298·45	7088·23
9 ,,	28·274	63·617	2·747	47 ,,	147·65	1734·94	74·948	96 ,,	301·59	7238·24
9½ ,,	29·845	70·862	3·062	48 ,,	150·79	1809·56	78·175	97 ,,	304·73	7389·82
10 ,,	31·446	[illegible]	3·393	49 ,,	153·93	1885·74	81·462	98 ,,	307·87	7542·98
10½ ,,	32·[illegible]	[illegible]	3·740	50 ,,	157·08	1963·50	84·801	99 ,,	311·01	7697·70
[illegible] ,,	34·[illegible]	[illegible]	4·105	51 ,,	160·22	2042·82	—	100 ,,	314·16	7854·00

Suggested Equivalents of Metric and British Weights and Measures.

1 drop of cold water sometimes is taken to = 1 grain.
1 gram = 15·438 grains.
1 c.c. = 2·2 septems. = 15·4 grains of water. Sometimes 20 drops are taken as one c.c. for microbe work.
1 kilogram = 15400· grains = 2·2 avoirdupois lbs.
1 litre = 22000· septems. = 2·2 decigallons.
1 septem. = ·454546 c.c.
1 decigallon = 454·546 c.c. = 1 lb. of water.
1 gallon = 4545·46 c.c. = 4·54546 litres = 10 lbs. of water, or taken as such.
1 decem. = ·649351 c.c.
1 fluid drachm = 54·6875 grains = 7·8125 septems. = 3·5511 c.c.
1 minim = ·91146 grain of water.
20 cwt., at the present time, is 1 ton of lead.
19½ cwt. = 1 fodder of lead in London.
21 cwt. = 1 fodder of lead in the North.
A weigh of lead was, by Edward I., 168 lbs.
A weigh of lead, by Statute 9, Henry VI., is 224 lbs.
A clove of lead is, since Henry VI.'s time, 7 lbs. In the time of King Edward I. it was 8 lbs. N.B.—This old trade weight for *lead* has been lost for about 300 years, and was found by myself in the year 1894, after twenty years' search at different intervals.

As sometimes you will be called upon by electricians, chemists, &c., to work from the French measurements, an insight to the same should be known by every plumber, for I have found it very awkward, when, as I was suddenly called upon to make some accumulators and plates for electric storage or secondary batteries some years since, when the engineer, a German, told me the plates were to be so many millimetres thick, so many centimetres wide, and so many decimetres long, which was quite to me unintelligible and threw me into a perfect fog. However, I groped my way out of it without being noticed, and you may be sure I very soon made myself acquainted with the following:—

1 millimetre	=	0·0393709	English inches.
1 centimetre	=	0·3937079	,, ,,
1 decimetre	=	3·937079	,, ,,
1 metre	=	39·37079	,, ,,
1 decametre	=	393·7079	,, ,,
1 hectometre	=	3937·079	,, ,,
1 kilometre	=	39370·79	,, ,,
1 myriometre	=	393707·9	,, ,,
1 are	=	1076·4414	square feet.
1 stere	=	35·3171	cubic English feet.

These measurements may be brought into English measure as follows:—

Divide the divisible by 12 for feet, 36 for yards, or 63,360 for miles. The myriometre is 6·2138 miles.

The centimetre $\frac{1}{0\cdot39}$ &c., *i.e.*, 2·54 centimetres nearly to the inch, and the millimetre being a tenth of that is 25·4 millimetres to an inch, a number to be remembered if you wish to use the French system, which I must say is easy to our system.

I may add that you can get the French rules at the rule maker, given in this work.

TOWN WATER SUPPLY.

Cast Iron Pipes.

Table of the Working Strength of Cast Iron Pipes, Weights and Thickness.

I have said sufficient upon the source of the London water supply, and will now give just a few hints respecting the mains. I will assume that my readers are thoroughly acquainted with cast-iron street water mains, which are made from 2in. upwards. The 2in. are made in 6ft. lengths, which may be had of various thicknesses suitable for different heads of water, of which the following table will give the reader a general idea:—

Diameter in inches.	Length exclusive of socket.	Head of water, 100ft.				Head of water, 250ft.				Head of water, 100ft.			
	Feet.	Thick.	cwt.	qr.	lb.	Thick.	cwt.	qr.	lb.	Thick.	cwt.	qr.	lb.
2	6	·30	0	1	19	·31	0	1	20	·33	0	1	23
2½	6	·31	0	2	3	·33	0	2	7	·35	0	2	11
3	9	·33	0	3	21	·35	1	0	3	·38	1	0	9
4	9	·37	1	1	15	·39	1	1	24	·43	1	2	13
5	9	·39	1	3	5	·42	1	3	21	·47	2	0	19
6	9	·42	2	1	6	·45	2	1	25	·51	2	3	6
7	9	·44	2	3	8	·48	3	0	9	·55	3	2	4
8	9	·46	3	1	10	·51	3	2	23	·59	4	1	4
9	9	·48	3	3	17	·53	4	1	7	·63	5	0	14
10	9	·51	4	2	10	·57	5	0	15	·67	6	0	4
11	9	·54	5	3	6	·61	6	2	6	·73	7	3	11
12	9	·59	8	0	6	·68	9	1	4	·83	11	1	9

The strength of the material to resist internal pressure is not all that is required for street water mains, but you should consider that the pipes should be of a sufficiently substantial character, and deep enough laid to bear the pressure from the traffic along the roads; and although water pipes may be of the above thicknesses, yet they are seldom of a uniform thickness, owing to the fact that the moulder, when fixing the cores, very seldom can guarantee that the core shall be perfectly central. For instance, a pipe whose substance is supposed to be ¾in. thick oftentimes will be found to be ⅞in., or even 1in. on one side, and ½in. to ⅝in. on the other. Then again, sometimes the pipes will, though unseen or otherwise undetectable, even when the pressure is put upon the pipes, be found to contain blow holes—*i.e.*, the metal will be spongy. In fact, I have seen these pipes broken, after they have been subjected to almost every conceivable test, turn out after some years in use to cause no end of trouble. Often these spongy holes will run half way round the pipes.

It should be borne in mind that it will be best to specify the weight of the pipe rather than the thicknesses, and leave a fair margin for the variations, as the founder is not expected to cast the exact weight, therefore allow a margin of, say, between 3 and 5 per cent.

Jointing.

The best way of jointing pipes is by caulking with spun yarn and running with lead. Generally this caulking room is for, say, 3in. pipes about ¼in., and from 3in. to 10in. pipes $\frac{5}{16}$in. to ⅜in., and as illustrated at the joint in

Fig. 940. The following table will give you a general idea of this :—

PROPORTIONS OF JOINTS ON IRON WATER PIPE SOCKETS.

Diameter of pipes.	Depth of Sockets.	Thickness between sides of Socket and Spigot.	Depth for the Lead after Spun Yarn.	Lead allowed, for Waste and Work.
Inches.	Inches.	Inches.	Inches.	Pounds.
2	3	¼	2	2
2½	3¼	¼	2	2½
3	3½	¼	2	3
4	4	5/16	2¼	4
5	4	5/16	2¼	5
6	4¼	5/16	2½	6
7	4¼	5/16	2½	7
8	4¼	5/16	2½	8
9	4½	5/16	2¾	9
10	4½	5/16	3	10
11	4½	⅜	3	11
12	4½	⅜	3¼	12

With regard to the cost of laying, this varies with the amount of labour for digging the trenches and the cost of labour in different localities; but the prices on the average may be roughly calculated as follows in and about the suburbs of London, macadam road, and 2ft. 6in. to top of pipes :—

PER YARD (INCLUSIVE).

2in.	1/0	4in.	1/3	7in.	1/10	10in.	3/4
2½in.	1/1	5 ,,	1/5	8 ,,	2/1	11 ,,	3/11
3in.	1/2	6 ,,	1/7	9 ,,	2/6	12 ,,	4/6

Iron Pipe Jointings, and Prices of.

The following is taken from one of my old day books of a job which I did ten years ago, near Salisbury, and will serve to give an idea as to the number of men for carrying out the job where the length of piping is stated together with the sizes :—

"Soft road ground. Trenchers' time : 16 men getting out trench and filling in, including lifting in pipes, total length, 3,320 yards of 4in., 27 days each. The joints were made by two first-rate jointers. They made 30 per day each man, but the fire and lead-pot were attended to by a boy. Spun yarn ¼lb. to a joint. Lead for jointing will run on the average 1lb. to the inch—that is, a 6in. pipe will take 6lb. of lead; but this depends upon the jointer. Some men will use half as much again as others, and then have bad work. The secret of jointing is to properly ram up the spun yarn true and even, so that the lead will form a true ring. Then the lead should be run not too sparingly nor too full, but just enough to fill the socket flush; for if you have too much you cannot drive it home on account of a flange forming round the joint, and if not sufficient then you will split the socket with the end of your caulking chisel."

Sometimes the ends of the pipes are fitted as at the union in Fig. 964, and ground together, then pulled up with two or more strong bolts and nuts with lugs, especially used for the London hydraulic mains for water power, lifts, &c.

THEORETICAL STRENGTH OF LEAD PIPES.

LEAD PIPES.				LEAD-ENCASED PIPES.		
Internal diam.	Thickness.	Weight per foot.	Bursting Pressure per sq. in. in lbs.	Thickness.	Weight per foot.	Bursting Pressure per sq. in. in lbs.
Inches.	Inch.	lb.		Inch.	lb.	
½	·2	2·3	1579	·14	1·3	1859
⅝	·2	2·6	1349	·13	1·4	1454
¾	·22	3·8	1191	·15	1·9	1416
1	·2	4·1	911	·14	2·4	1265
1¼	·21	5·3	683	·13	2·7	835
1½	·24	7·1	734	·15	3·8	849
2	·21	9·2	498	·17	5·4	642

The tearing strength of lead pipes was 2,159lb. per square inch, and of lead-encased pipe 3,759lb. per square inch.—*Kirkaldy's Experiments.*

For this we will also take our calculations from Barlow's rule, which runs as follows, taking the cohesive strength of drawn lead at 2,745lb. per square inch :—

$$T = \frac{R + P}{S - P}$$

$$P = \frac{S \times T}{R + T}$$

$$S = \frac{(R + T) \times P}{T};$$

In which S = the cohesive strength of the metal per square inch.
,, P = the internal pressure per square inch, in the same terms as S.
,, R = the radius of the inside of the pipe in inches.
,, T = the thickness of the metal in inches.

The above is Barlow's rule for thick pipes, but for thick pipes such as those which the plumber has *generally* to do with, and in order to provide adequate strength there is nothing to equal practical testing; but for our purpose we will adopt the following hard and fast rule, which takes the form below :—

$$t = \left(\frac{\sqrt{D}}{10} + \cdot 15\right) + \left(\frac{H \times D}{2,500}\right);$$

In which D = the diameter of the pipe in inches.
,, H = the safe head of water in feet.
,, t = the thickness of metal in inches.

The following table can be obtained, therefore, from Barlow's rule, where we take the cohesive strength of the lead at 2,745lb. to the square inch, which is from direct experiment on lead; and as lead pipes are pressed with various kinds of *soft* and *hard* lead and to various weights (see my *Practical Lead Pipe Tested* Table on page 36) to s[illegible] the different heads of water, and taking an ordinary *tem ature* and the medium weights, deducting the thickne therefrom, the following table will be found in which safe working pressure is by some engineers (though by too much) taken at one-tenth of the bursting strain. I [illegible] here again remark that there is nothing but real pract and the qualities of lead to be depended upon in tests

lead pipes, no matter how carefully worked out theoretically:—

Diameter of Pipe	½"	⅝"	¾"	1"	1¼"	1½"	1¾"	2"
Weight of Pipe, lbs. per foot	1·33	1·47	1·87	2·80	4·33	6·0	6·75	8·0
Safe Pressure in feet of water	232	183	174	151	152	140	122	116

See also Lead Pipe Working Strength of Pump Table.

By comparing this table with the table of weight, and working strength of lead pipes on page 36, it will be seen that the ½in. pipe, No. 20, in my practical working table is below the table above, about 32ft.; but the ⅝in., No. 22, is 200ft. in my table on page 36, whilst that in the above table is 183ft., showing a difference of only 17 between the practical and theoretical; but if you examine the inch, No. 42, in the practical table, and compare it with the inch in the theoretical table, you will there see a wide margin, the theoretical being 51ft. above that of the practical table; and on examination of 1¼in., No. 52, in the practical table, and comparing it with that of the 1¼in. in the theoretical table, a difference of 98ft. will be seen; and in the 1½in. a difference will be seen of 110ft., the theoretical table being this much lower; and the 2in. varies to the alarming amount of 184ft., the theoretical table being this much below the practical working table, which I can only account for by allowing, in these large pipes, the working pressure to be taken at one-tenth the bursting strain. So much for the thicknesses of the walls, and their resisting power.

Weights of Pipes and Castings.

The weight of pipes and cylinders is often required by the surveyor and engineer. The rule to find the weight in pounds is to subtract the square of the inside diameter in inches from the square of the outer diameter in inches. Multiply the result by 7·4 and divide by 3. Multiply lastly by the length of the pipe in feet. The weight of castings may be determined thus:—Multiply the width in quarter inches by the thickness in eighths of an inch, and divide the product by 10; then multiply the result by the length in feet. For wrought iron add $\frac{1}{30}$ to the result. Flat castings and bars are of constant requirement, and their weight can be found by the simple rule of multiplying the width in inches by the thickness in inches, and by the length in feet, and then for cast iron by 3⅓, and for wrought iron 3⅓. Tables of these weights will be found in every handbook; but the simplicity of the above rules commends them to all those who are in frequent want of such information.

Elm Water Pipes.

[illegible] water supply to towns, &c., wooden [illegible] such as is shown at Fig. 780, and even [illegible] cities of the United States, where [illegible] the old wooden water mains [illegible] unsatisfactory results. [illegible] employed in England [illegible] articles were first [illegible] which were in use in [illegible] had flanges, which, [illegible] published in [illegible] water, water [illegible] wood; the [illegible] of iron [illegible] feet and [illegible] together [illegible] or old [illegible] are [illegible]

length is usually about that of the iron pipes." I have seen these pipes, both in iron and earthenware, and the description is exact. The earth pipes were made thinner than those of our day, and are more of the shape of a cone, and without collars. To make their joints thoroughly watertight they used Roman cement, also tow and pitch, and for heavy pressures they used hot resin and mutton suet, with tow; and an excellent joint was made. We boast of our drainpipe jointing; but where are joints now to be found on drainwork made better than those of eighty years ago?

I have said that the joints on the iron pipes of 1803 had flanges; but the spigot, or socket joint, was well known at that date, for nearly all the wood or tree pipes had spigot joints. Some were made by driving one end into the other, whilst others were made exactly as we make ours at the present time—with spun yarn and lead—except that the front part of the male end was made to fit, cone-shaped, into the socketed end, as shown at B, Fig. 780. The outer part of the female end was made slightly tapering, and stout iron rings, C, E, were driven up, to tighten the outer part on to the lead and yarn. The lead could not get out, no matter what pressure was put behind it, owing to the fact that the male end of the joint was cone-shaped: in fact, the stronger the pressure the tighter the joint became; the spun yarn being pressed against the lead prevented the escape of water. I may state that Fig. 780 is a similar drawing of an old joint, which I found whilst cutting a drain for St. Margaret's Church, Lothbury, London, in the year 1879; it was about 9ft. down from the level of the roadway.

One thing is quite certain, that the gas companies had to pay the piper at the commencement of their work—date about 1813—for we read that they had to pay from £18 to £20 per ton for cast-iron piping, which to-day is but little more than one-quarter the price. In France the gas companies at first (owing to the price of cast iron) used tinned sheet iron, riveted up, the thickness being about No. 16 gauge plate. The pipes had a coating of tar and a layer of asphalte, and some say that these pipes have lasted from thirty to thirty-five years.

Service Pipes from Street Mains.

Also see Building Supplies.

For Iron Pipe Work see Hot Water and Gas Fitting Work.

In laying these mains one uniform method should be adopted. They are, or should be laid, if regulated by the regulations of the Water Works Act of 1871, at a depth of 2ft. 6in., and out of the reach of the frost; but I say 3ft. 6in. to 4ft., to be properly out of the way of the frost.

It is always advisable when the ground has to be opened to apply to the water company, as in many parts they do it themselves; whilst in other districts the plumber has to get it done. When the latter is the case the plumber invariably has to apply to the vestry or local board authorities for a license for breaking up the road.

In Kensington we have to deposit a sum of £1 to defray the expense. After the work is completed, and all made good to the satisfaction of the authorities, the balance is refunded.

Lead Pipes.

There are but few good even lead pipe makers. The first two in my opinion are Messrs: F. A. Clark & Son, of Hammersmith, and Mr. Chatterton, of King's Cross, whos[illegible] very largely used. [illegible] poured hot enough to prevent cold [illegible] heat of lead so as to withstand

the turn pin against easy splitting or bad pressed pipe, which should always be rejected as worthless: also look out for breaking pipe when bending such rotten stuff.

The lead pipes used for this kind of work are generally supplied in coils, as shown at W, Fig. 960. The size of

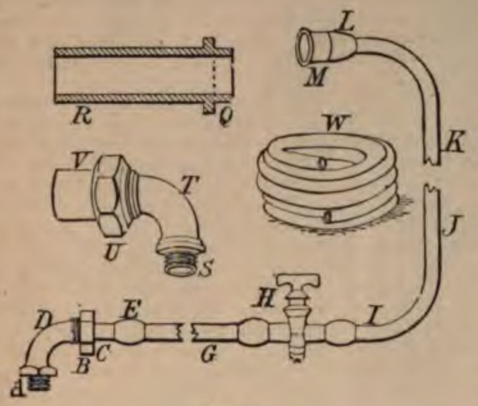


Fig. 960.

the lead pipes to be used depends upon the company. Some will have a certain size of pipe with a certain substance, whilst others do not trouble themselves much in the matter. The New River, East London, West Middlesex, Lambeth, and a few other water companies, enforce a lead pipe according to the Water Companies' Act of 1871, of the following substance, viz. :—

Diameter Inches.	Weight of Lead Pipe in lbs. per Lineal Yard.
⅜	5
½	6
⅝	7½
¾	9
1	12
1¼	16

Lead Pipe, Bursting Strain of.

On page 36, Vol. I., I gave a working table of the strength of lead pipe, which I for years have used, and has proved satisfactory. I have also given Barlow's rule of the working strength of lead pipes. (*See* Theoretical Strength of Lead Pipes.)

Brass Work—Ferrules.

The old class of driving ferrule is shown at A, Fig. 961, which was used up till the year 1870.

It had simply a brass tapering inlet end, rough file drawn to drive into the wooden or iron pipe, after having made the plumber's joint on the outlet end.

A Fig. 961. B

B, Fig. 961, is a straight (screwed at one end) ferrule, for screwing into the iron mains.

The ferrule used on the New River, East London, and a few other companies about London, is shown at V, U, T, Fig. 960. This is simply a bent ferrule screwed at A, Fig. 960, to ⅜in., ½in., ¾in., or other size gas thread, but should be screwed well tapering, so that it will tighten up as it enters the tapped hole in the main, &c. B is the nut to screw the lining E on to the bend D. The lining E is soldered on to the lead pipe, as shown at C, E, Fig. 960. At S, T, U, V is shown a ferrule for iron barrel screwed at V. Old driving ferrules were used before the screw ferrule was invented.

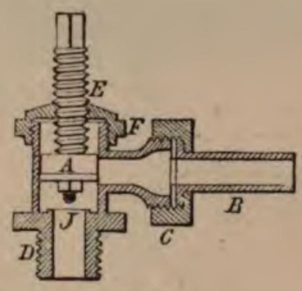


Fig. 962.

Figs. 962 and 963 show a kind of stop-valve ferrule, suitable for shutting off the water. A is the valve and J the seating, C is the union nut and B the lining, E the screw for working the valve, and F the top. In this valve it may be seen that the water has every chance of passing between the screw and the top, but on closely

Fig. 963.

examining the diagram it will be seen that under the cap is fixed a leather washer, and by turning up the top part of the valve tight against this washer all chances of a by-pass are stopped. If you closely examine the end of the lining at Q, Fig. 960, and that at A, Fig. 964, you will see that the end of the lining protrudes into the union, which will prevent a solid disc being placed between the end of the lining and the end of the union. Now examine C, Fig. 962; here you will see that the end of the lining is flat and butts up against the end of the screwed part of the ferrule and will admit of a leather washer being placed between the end of the lining and the end of the ferrule or union; but suppose instead of this leather washer that a plain disc of leather be used, it will be plain that no water can pass, and should the pressure be too strong a copper coin may be placed at the back of the leather to strengthen it. This is a very good plan for cutting off the water. I have

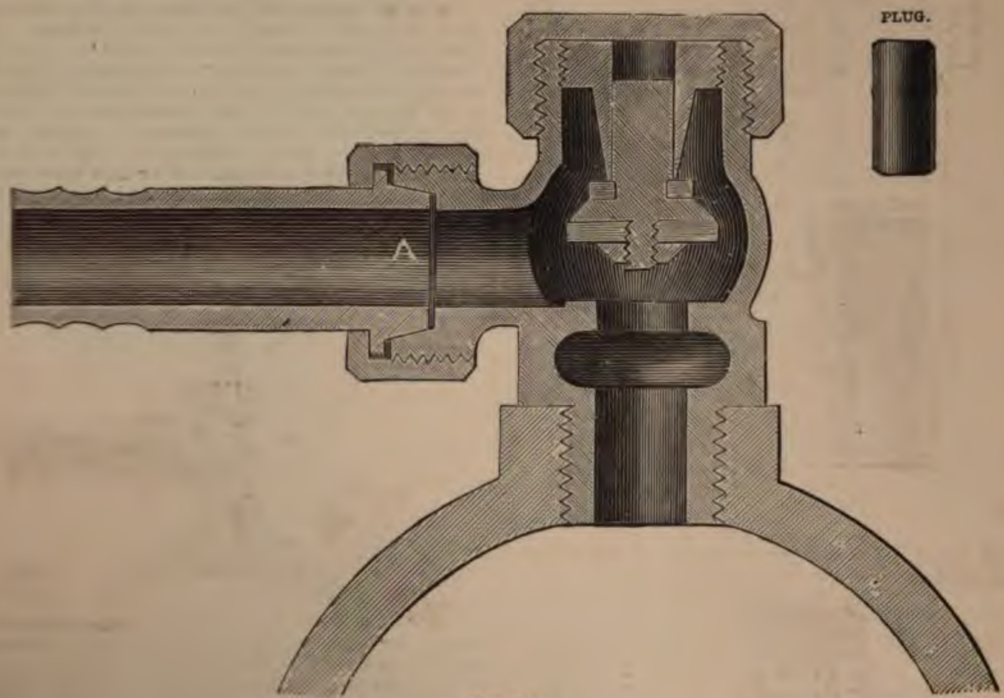


FIG. 964.

[illegible] the end of the lining cut off [illegible] off the water, instead of [illegible] the valve A, Fig. 962, or, as [illegible] screw ferrule A, B, and [illegible] is a valve-screw ferrule [illegible] spindle, which is protected [illegible] made by Messrs. J. Tylor

[illegible] Ferrules.

[illegible] of the late Mr [illegible] Water Works. [illegible] the West Mid- [illegible] thoroughly explains [illegible] that the union [illegible] the chances of [illegible] all that has [illegible] in the pin [illegible] the top [illegible] upon the [illegible] top of the

In the first [illegible]
pipes were [illegible]
now some of [illegible]
wood is cheap [illegible]
have been reviv[illegible]

Cast pipes [illegible]
before the year [illegible]
made in England. [illegible]
the year 1803 had [illegible]
according to G. Gr[illegible]
the year 1807, is as [illegible]
engines, &c., are usu[illegible]
latter are commonly ma[illegible]
are cast in forges. Their [illegible]
a half. Several of these [illegible]
by means of four screws at [illegible]
hat between them to stop th[illegible]
made by the potters. These [illegible]
one end being always made wid[illegible]

square recess, so that a small tee spanner can be inserted in it through the hole in top cap, and the plug valve readily screwed down or opened as required. Th top cap, besides protecting the plug valve from grit and dirt, prevents the

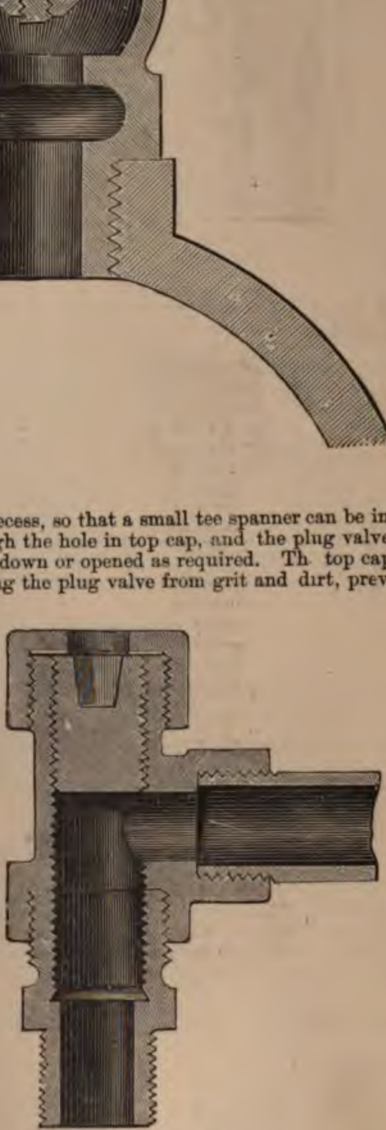


FIG. 965.

possibil[illegible] its being screwed up too high. These ferrules ar[illegible] tapping the mains under pressure as at Fig[illegible]

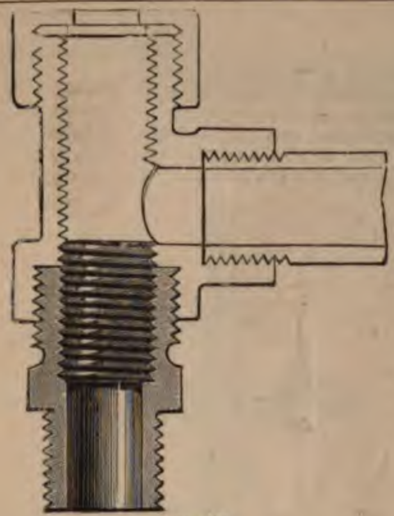


FIG. 966.
(*See also* Fig. 970.)

Mains (Tapping).

I will now explain and illustrate one or two of the simplest methods of tapping the mains.

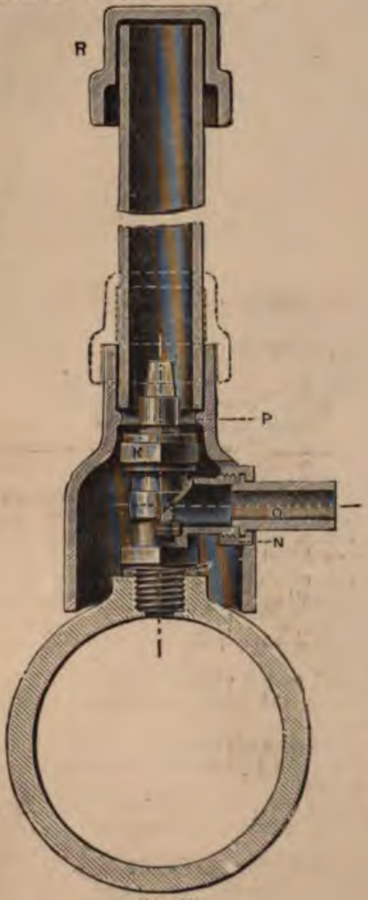


FIG. 967.

Having the ground open down to the main, and the waterworks' man on the job (who generally about London does the work), commence the work as follows. Say the hole is to be drilled as shown at Fig. 967.

The main being empty, put on the clamp, *without the tap drilling arrangement*, as shown in Fig. 968, and drill the hole; afterwards tap it with a suitable-sized gas thread tap. It will not always be necessary to use the clamp and block as shown at Fig. 968, as only one or two water companies in London require this arrangement, and where such is in force, they usually send out the clamp already tapped.

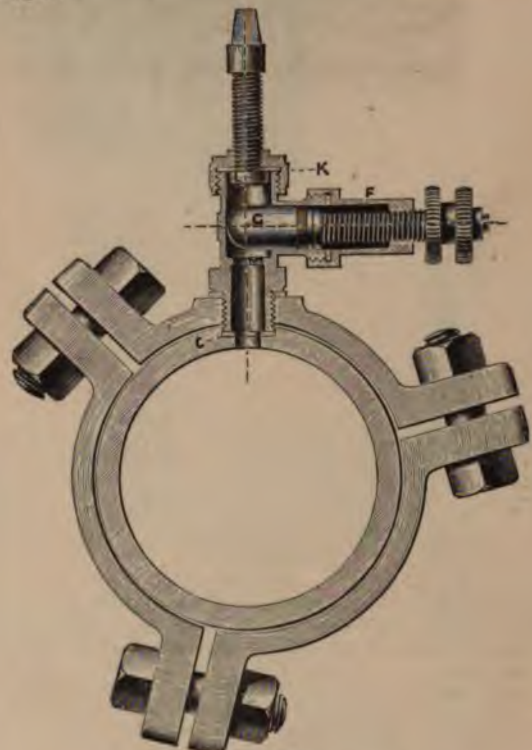


FIG. 967A.

Tapping Mains (without Drilling).

Sometimes it happens that you will not have drilling tackle to tap the main with. In such cases, you will be able to do this job with a diamond-pointed tool or chisel—and there are many men who prefer to cut their holes this way to that of having the trouble of carting about the drilling tackle; but it must be remembered that you must keep your diamond point to a good shape and sharp, and, when cutting the hole, go gradually cutting all round in a circle to about the size of the hole, great care being taken not to strike too heavy blows, which would split or otherwise injure the main. After you have thus cut the hole, it must be reamed round and tapped as before.

Tapping Water Mains under Pressure.

This system of tapping the mains, which allows of the holes and the connections to be made, notwithstanding the pressure being full on, is of great value in towns or other places where the shutting down would inconvenience manufacturers and the like, and will be readily understood

from the following description and illustration. Brown's Patent Ferrules; sole makers, Messrs. J. Tylor & Sons.

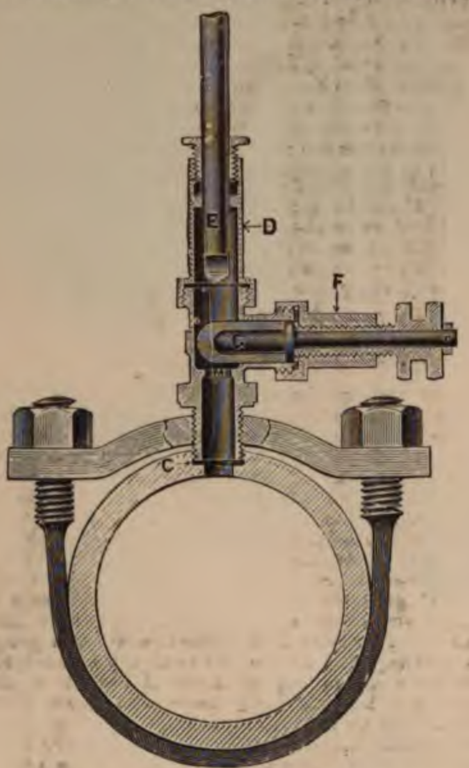


FIG. 968.

For ordinary mains the ferrules are supplied with clips, which obviate the necessity of screwing or tapping the main, nothing requiring to be done but drilling a hole in the main.

The method of attaching a service pipe is as follows:—

By means of the usual ratchet brace and a drill, shaped as shown at A, Fig. 969, a recess is bored in the top of the pipe, as shown at B, the workman ceasing to bore as soon as the point of the drill pricks the water.

The cock and clip are then placed in position and secured by tightening the clip by the two nuts and by screwing the ferrule in the clip, a joint being made by the lead washer C; or the joint may be made with leather packing between the clip and main pipe, and the ferrule screwed firmly into the clip as with the ordinary screw ferrule.

The top of the cock, with the valve and its spindle, are then removed, and the drill guide D with drill E are fixed in their place; the cap and lining are removed from the outlet of the cock, and the chamber F and plug G are screwed on in their stead, as shown in the diagram.

The drill E is then forced down and the hole drilled right through; a small stream of water is at the same time allowed to escape by the petcock H to carry away the iron borings.

The drill E is now withdrawn into the position shown in Fig. 968, and the plug G is screwed home, as shown.

The escape of water being thus prevented, the drill guide D, can now be taken away and the top of the cock K, and permanent valve L, put on as shown in Fig. 967A.

The plug G, is then withdrawn within the chamber F, and the permanent valve L, having been screwed down upon the seat M, the chamber F with its plug G, can be removed, and the cap and lining, N, O, Fig. 967, replaced, and the laying of the service proceeded with.

It will thus be seen that the whole process is very simple, and needs no further apparatus than the pieces D and F, which, of course, serve for an indefinite number of cocks.

Any form of clip may be used; the kind shown at Figs. 968 and 969 is very strong and cheap, consisting of

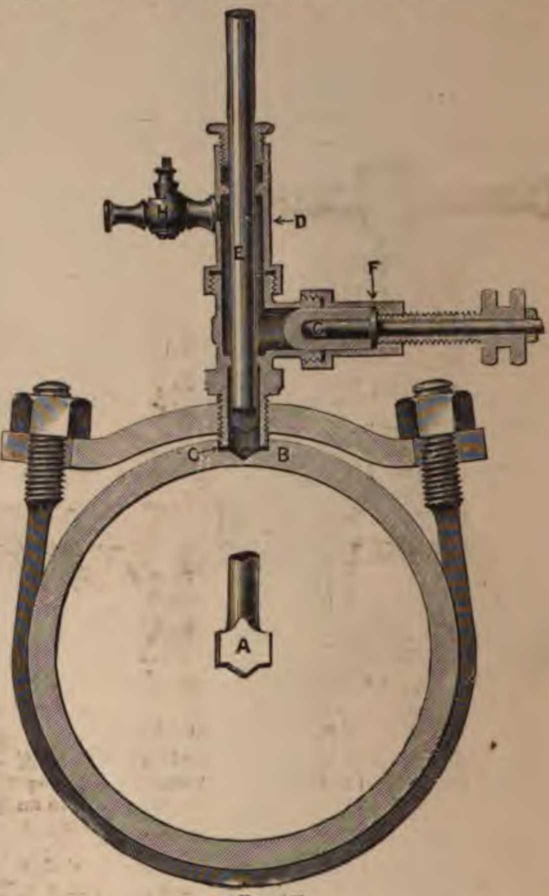


FIG. 969.

galvanised cross-bar, and flat band beneath the pipe terminating in two ⅝in. screws as shown.

Where bosses, as at Fig. 967, are cast on the pipes, or where a sufficient thickness of metal exists to enable a proper depth of screw thread to be obtained without entirely penetrating the pipe, it is obvious that clips are not required.

Cast-iron bell covers, P, are provided as shown in Fig. 967.

These stand on the pipe, and do not touch either the cock or the clip, and thus the cock is effectually protected from injury.

Where the mains are deep, it is a good plan to carry up a piece of 2in. gas pipe to near the road surface, covering it with the cap R.

Then, at any time, with the aid of a long key, the water may be shut off, without the necessity of digging down to the main.

Fig. 970 illustrates Messrs. Stone & Co.'s method of

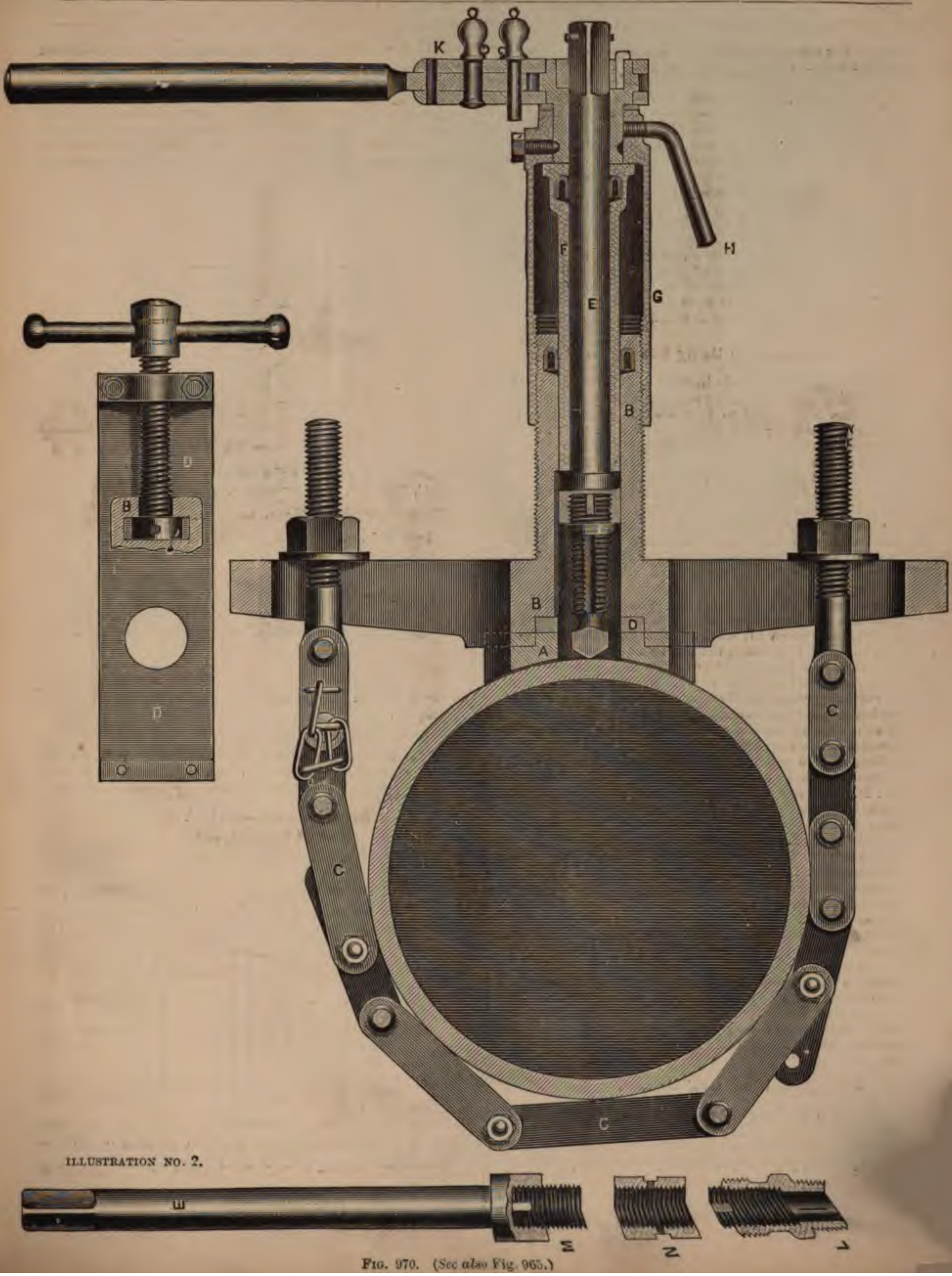


FIG. 970. (See *also* Fig. 965.)

tapping the main under pressure of water. The following is the description:—

One of its principal features is the introduction into the patent ferrules used in connection with it of a plug valve, the object of which is to close the communication between the inlet and outlet of ferrules, while it is being attached to the main. When the ferrule is fixed to the main, and connections attached, the internal plug or valve is raised, so opening up a free communication between the inlet and outlet of ferrule, and allowing the water to pass into the service pipes.

The apparatus is of the simplest, and yet the most perfect kind, and although exceedingly strong, it is very portable. The saddle piece B, is made so as to be used with different saddle packing pieces A made suitable for different diameters of main pipes, so that one saddle piece can be used with various sizes of main pipes by simply changing the packing piece A at its underside.

Directions for Using the Apparatus.

To drill and tap the hole in main under pressure:—Place the packing piece A, on the pipe over the point where the connection is required to be made, the joint between the packing piece and pipe being made by greased felt or other suitable material. Fix the saddle piece B, in position by means of the chain C; place in position the steel slide D, with the hole in the same over the spot in main, where the connection is to be made. Insert the spindle E, with drill tap attached in boss on saddle piece, having at top a cup leather to prevent leakage, slip the internal sleeve F (also fitted with cup leather, which sleeve transmits the feed to drill) over spindle, and screw the outer sleeve G, with cramping screw H, and screw pin I, (slackened out) on to saddle piece. Place the double ratchet K, in position, and tighten screw pin I, insert the pin giving right-hand motion in pawl of ratchet, and commence to drill, tightening up cramping screw H, when necessary to get feed on drill.

When drill is through the main and commencing to tap, keep the screw H, tightened continuously, and the tap will work down at its proper speed. Withdraw tap and drill by reversing pin in pawl of ratchet, thus giving left-hand motion to same; close slide D, remove drill tap from socket of spindle, and replace same when fixing 1in. and $1\frac{1}{4}$in. ferrules by a screwed plug M, which projects below spindle [illegible] and to which plug is screwed the lower part of [illegible] ferrule L containing plug valve (see illustration [illegible]). When fixing ½in. and ¾in. ferrules the socket N [illegible] the top part of same being screwed to bottom of [illegible] and the lower part screwed over lower part of [illegible] ferrule I. (See Figs. 965 and 966.)

[illegible] spindle with these attachments is again inserted as [illegible] after the slide D is withdrawn from covering [illegible] and tapped hole, the lower part of ferrule is [illegible] the hole by means of the spindle and ratchet [illegible]. When this is done, the whole of the [illegible] having the *lower part* of patent [illegible] the plug valve in main.

[illegible] of the ferrule, having the cap screwed [illegible] to part in main, and the service [illegible] of same in the ordinary way, [illegible] plug valve is unscrewed by a [illegible] projection on top of plug or [illegible] as preferred.

[illegible] Unions.

[illegible] Figs. [illegible] and 973, and are for [illegible] lead or other pipes together, [illegible] of the making of a joint, [illegible] that occasionally have to be taken apart. These unions are very numerous in design, some having round entrance ends whilst others have

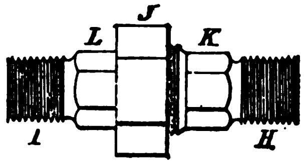


FIG. 971.

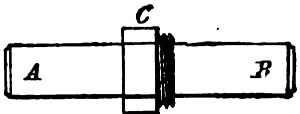


FIG. 972.

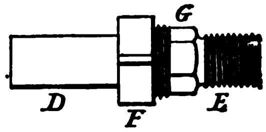


FIG. 973.

square, which prevents the female end turning when the nut C, Fig. 972, is being turned.

Hose Unions.

These unions are shown at Figs. 974 and 975, and are

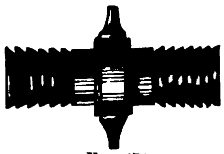


FIG. 974.

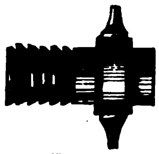


FIG. 975.

largely used in fire-engine work, garden supplies, brewery work, &c.

Barrel Union, one end for Lead.

This union is illustrated at Fig. 978, and is for the purpose of connecting lead to iron pipe, such as a stout piece of ¾in. or 1in. to the hot water supply to baths, &c.

Barrel Union.—Male Thread.

This is illustrated at Fig. 973, and is used, as at V, W, Fig. 1,578, &c., instead of the connector M, K, Z, Fig. 1,591.

Barrel Union (ordinary) with Female Screw.

This is illustrated at Fig. 976. A, B, are the two ends screwed inside to suit the screwed ends of the pipes. The

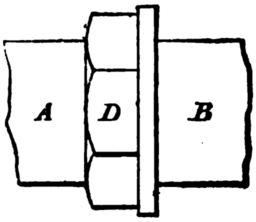


FIG. 976.

end B of this union (under a pinch) may be tinned and soldered on a lead pipe. Tin the lining up to the shoulder

near the outside screwed part; but Fig. 979, which is a strong union of good shape, should be used where price will allow.

Barrel Union with Squares on the Linings with Female Screw.

This is shown at E, F, Fig. 977, and is for the purpose of screwing on the linings with the screw wrench, instead of using the gas tongs, which are apt to cut and mark the outside of the linings.

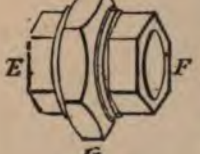


FIG. 977.

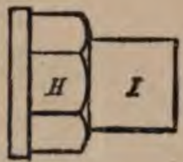


FIG. 978.

FIG. 979.

Fig. 978 is a ferrule for screwing on to iron pipe, and for making good iron to lead without the nut and linings.

Unions with flange and fly nut are for iron, slate, or other tanks where the cistern is required to drain itself dry.

FIG. 980.

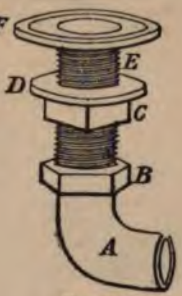


FIG. 981.

The diagrams, Figs. 980 and 981, need no further description.

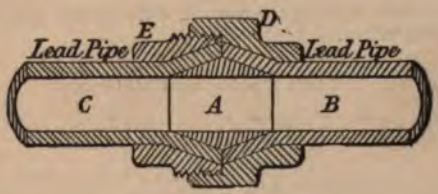


FIG. 982.

Union Joints.

It will sometimes happen that you will be required to repair a lead pipe when the water cannot be quite turned off, and that you cannot use solder; under such circumstances a union of some description must be used—for such refer to Fig. 982. A, is a cone-shaped socket; E, a kind of screwed lump, with an externally square lining, the inside of which fits the pipe, and presses it upon the cone-shaped socket; D, the nut, is made as shown, to grip the lead fair on to it, similarly as at E. Now examine the elevation

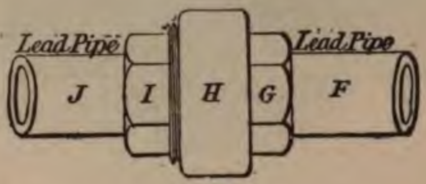


FIG. 983.

F, G, H, I, J, Fig. 983. Here you will see that by opening the ends of the pipes, and placing the cone-shaped socket A between them, and by screwing the two nuts together, that for temporary work a sound joint may be made.

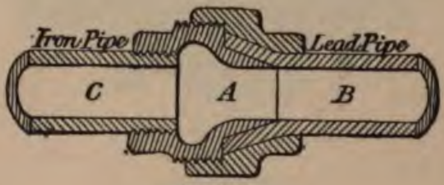


FIG. 984.

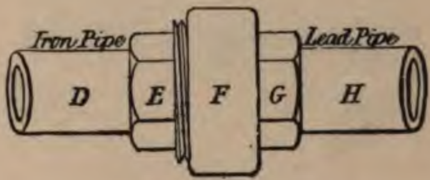


FIG. 985.

Fig. 984 is the same kind of thing, but the one end is screwed for iron. Fig. 985 is the elevation of Fig. 984.

There are various kinds of these connections, couplings, or unions in the market. Those above described are very good.

FIG. 986.

Fig. 986 illustrates the turn pin used for openi ends of the pipe suitable for the union, Fig. 982.

Figs. 987 and 988 illustrate Messrs. Stone's uni lead and iron pipes; the engravings explain the after what has been written about Fig. 982.

Figs. 989 and 990 illustrate the above union joint, both ends for lead.

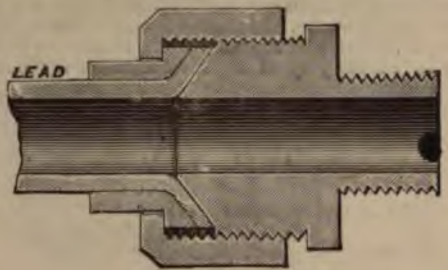


FIG. 987.

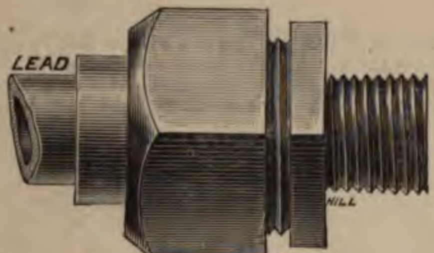


FIG. 988.

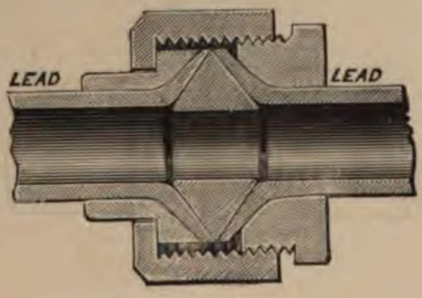


FIG. 989.

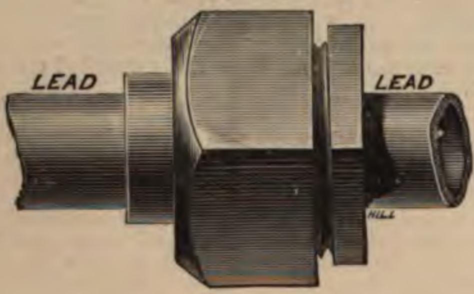


FIG. 990.

Figs. 991, 992, 993, and 994 illustrate union joints having the ends of the pipes butted together, and are too simple to require any further description after the previous explanation.

FIG. 991.

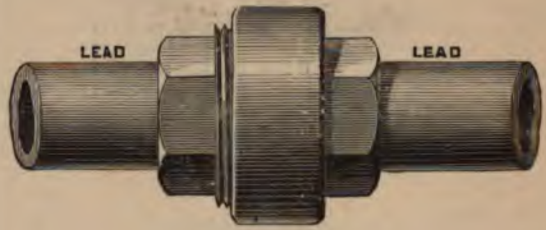


FIG. 992.

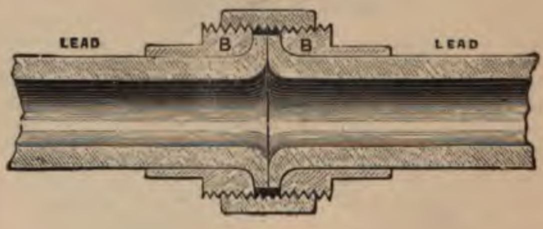


FIG. 993.

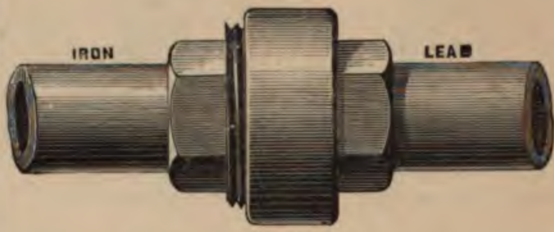


FIG. 994.

Having explained and illustrated the various kinds of unions and ferrules, the next in order should be the stop cocks or valves.

Stop Cocks and Valves.

(*Also see Hot Water Work, Cocks and Valves, and Closet Water Supply.*)

In the diagram, Fig. 960, may be seen the method of running a main; E, G, L, is the length of the lead pipe; H, an ordinary ground-in stop cock with crutch key, and square way wiped on the lead pipe. This cock is well illustrated at Fig. 995.

Fig. 996 is a round way stop cock, having a bow key, and a good class for places where it has to stand, perhaps, for twenty years without attention, because you can put a

bar of iron and such like to turn it, thus getting a good leverage, and a ready means of turning the key, and which, when left, should have the ways of the key straight and true to the inlet.

FIG. 995.

FIG. 996.

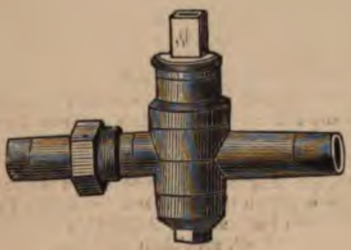


FIG. 997.

Fig. 997 illustrates the round way stop cock with square headed key, for places where it is required to use a key or spanner for turning. It also has a union at one end—a very handy appendage for disconnecting and connecting.

Gland Cocks.

Fig. 998 illustrates the gland cock, similar to that shown at Fig. 514; but Fig. 998 has two unions, which allow the cock to be taken out for repairs, &c.

These cocks are suitable for a very heavy pressure, and, where the cock after much turning, is likely to leak; this of all stop cocks I know of for dependence, say twenty or thirty years standing still, I think, if properly made, is the best. *Notice* that I say for stop cocks which stand still for long periods together, and that they must be of first-class pattern and make, and tested up to, say, 200lbs. to the square inch.

Fig. 998.

Gland Cock Packing.

When packing a gland cock take out the leather washer, and all the old packing; then with some good hemp and melted Russian tallow, pack the cock with hemp laid evenly round, but do not screw it down too heavily.

For other kinds of stop cocks (see from Figs. 512 to 526). See also globular valves, bib cocks, valves and bath work, sluice valves, hydrants, &c. It must be noted that some water companies enforce a different class, generally of the

FIG. 999.

valve kind, such as is shown at Fig. 999. This is known as the Rotherham pattern, and is good (so long as the leather washer lasts) as far as regards the stop cock, and is generally easily turned, but as the passage through this cock has so many sharp corners (see section, Figs. 518 and 1,014), it greatly adds to the power required to force the water from the main into the house, and I for one should certainly not use it · that is, if I should have to pump the water. If a valve cock must be used, then the water companies should, for their own sakes only, use one which has a straight water-way through it, as shown at Fig. 523. This also applies to ball valves. I may add that such ball valves are made.

Stop Valve Fixing Wrong Way About.

It is quite possible to fix the Rotherham cock the wrong way about—that is, to make the inlet the outlet (see Fig. 518, &c.). A, is the inlet; should you make E, the inlet, the force of the water will be upon the valve, and consequently will tend to keep it closed. In such cases the cock *should be reversed;* but the difficulty may be got ov by soldering the jumper (the valve) to the spindle. But such an occurrence takes place, keep it to yourself and aw from the ears of the water company; though in point law they cannot make you alter it, because the cock is the screw down kind, and the Act says nothing as t

whether the valve should be a fixed or a loose one. Having fixed the stop cock, see that it is well down and fixed out of the way of the frost, and in such a position that it is accessible, and can be easily got at for releathering, which is generally required to be done when the plumber wants to turn off the water, especially should the valve have stood without turning for a few years.

Repairing Valves and Cocks.

To repair valve cocks you must use your own discretion, for there are various kinds according to the makers, each one considering his own the best. I may here remark that care should be taken with the unscrewing and screwing, as often these articles get more injury from the rough plumber in five minutes than they do from their natural wear and tear in five years. A plumber who knows his business should be able to releather and repack any kind of valve cock; but, of course, he is not expected to grind-in cocks, though a plumber who can do such work will be considered an exceedingly useful man in country places.

Cock Grinding-in.

To get a general insight into such work, and in order that the plumber may judge good ground-in cocks, the following may be worth noticing:—First, the cock is cast—some with pot metal, viz., with a certain amount of lead in the mixture, just sufficient to make the metal softish for grinding-in. The barrel or shell is, for ½in. to ¾in. cocks, placed in a vice having clamps of lead, over which is fixed a nut in the ceiling to receive the one end of a boring bar, from 5ft. to 6ft. long, having a screw at one end, and from 6in. to 12in. long, something like a long screw for a connector. At the other end of this boring bar is a steel centre point, similar in shape to the point or end of a centre punch, the boring bar having an eye for receiving a lever, similar to the lever of a vice, for the purpose of tightening down the boring bar. Having this rigged up, and the shell of the cock fixed in the vice, place a four-square borer in the shell, the borer having four *very truly* lapped up or ground perfectly straight edges, made to the exact taper of the shell or key of the cock. Such taper is about one in six; if a greater taper the key will tend to work up, and if less taper it will be too apt to jam itself. On the top part of the borer there is fitted a square for a key or tap wrench, and on the top, and truly in the centre of the borer, there is a centre hole to receive the end of the boring bar, the latter of which is to keep the borer down in the shell of the cock whilst the borer is being turned: thus by turning this sharp cutting borer, under pressure from the boring bar, the borer is on turning made to descend, and so it bores the shell truly throughout. After this borer has been sent to the required distance to thoroughly clean out the shell, another borer is used, but this borer has to be steadied by means of a kind of half-round boxwood splints or packing, placed on the sides of the borers in such a manner that only a *little* portion of the cutting edges are to be seen. This puts a finish on to the boring, and the shell is ready for grinding-in. Larger sized cock shells, or bodies, are bored or "slid" out in the lathe cock keys. These are fixed between the centres of the lathe, and are turned down to the cone of the cock body or shell, care being required to get the right *bevel*, and that the key be turned true and without rings. Of such work is best done with a slide rest, fixed to the cock cone. To prove whether the cone is true, a line down the shell of the cock when trying the key, and this will tell you whether the key has an equal bearing. After the key is turned, screw the bottom, and file up the square for the bottoming nut washer.

After this is done, prepare for the grinding-in. This is done as follows:—Place the key of the cock in the vice sideways, and with the cock body placed between two hollowed out sticks, something like the shape of a rolling pin, in two halves, held together with two band rings, place the shell of the cock on to the key, and with some "mulley," which is a kind of loam, wetted to about the consistency of clotted cream, placed on the key, give the shell a good spin round. This works the "mulley" all over the bearing surfaces of the key. Then with the hands at each end of the cock sticks press lightly forward, and give it a turn or two backwards and forwards occasionally with a sharpish kind of a jerk, pulling the shell off the key; then adding a little spittle to the key (spittle is the best known lubricant for cock grinding) as a lubricant for the "mulley," great care being taken not to get it too dry, and to attend to the pulling off the shell in a kind of jerking manner. As explained, keep grinding until the key shows that it *bears at every point*, or better, a little hard at top and bottom, which must be carefully watched for. Look out for the "rings," which will appear about the water-way of the cock, proving that you have grit, which must be removed, and when seen, stop grinding, and wipe the "mulley" away. Grind the key and shell quite smooth, after which grease the key with a little good tallow candle. Next make your bottoming nut washer, which may be faced up by causing it to revolve in the lathe, and by holding a smooth file against it when revolving. The cock is now put together, and again placed between the centres of the lathe, and the bottom of the shell turned true and finished. Sometimes the bottom of the shell is turned true on an old key before the grinding is done.

Sometimes, when the "mulley" cannot be obtained, the dirt from the trough of a grindstone is used for cock or valve grinding, which, if quite clean, answers very well; but you must not be too heavy with it, using plenty of spittle for lubricating.

Emery is of no use for first-rate cock grinding. The above is the method of work as practised by my own cock finishers at my late works at King's Cross Patent Valve Works, and as practised by the best Birmingham and London cock finishers.

Of course, the brightening up of cocks is done by filing up first with a rough or "bastard" cut file, then with a fine one, and then burnished. After this they are cleaned with brickdust and oil, and then polished with brickdust and list.

Sometimes the finishing of shell pattern cocks are finished in a pole lathe.

Cleaning and Polishing Brass and other Cocks.

Mix some brickdust or emery powder in oil, and rub the cocks well all over with this, and, with some long slips of carpet list, polish with dry powder. It will make the cocks appear as quite new, but do not get any of the powder into the bearings of the cocks or valves.

Jammed Cock Keys.

Sometimes you will find a plug of a cock jammed or set in the shell; the least knock on the top of the key will often do it. When such is the case, unscrew the bottoming nut, level with the bottom of the plug screw thread, and with a lead dummy lightly tap it upwards. If it will not move, just quickly warm the shell so that the key does

not get hot (put a little paraffin on the plug), and try to turn the key, but do not go like a bull at a post and wrench off the crutch. Use for crutch key cocks a pair of gas tongs of suitable size, and after a little trouble you will most likely get it to move; then take it out and tallow it, refix, and another job is done; but sometimes you will have to cut it out and fix a new cock, as you might have brazed or skinned the working parts of the cock by torsion, &c.

Draw-off Cocks, and Testing Same.

I shall now show you a few of the cocks in general use, and you must select those most suitable for your work, taking care that you always select those which will turn without jumps or work gritty. To temporary test a cock shut it off and suck at the inlet; if it hangs to your lip for a time without any sign of giving way it will do. Ground-in cocks may also be tested by making a small bladder or spittle on the one end, say, at the snout, and by hard continuous blowing at the other end, try to blow through the cock sufficient air to burst the bladder, or to cause it to become large like a soap bubble. Thick soapy water and air from a good air pump is an excellent test: or by placing the cock in a pail of hot water and under a pressure of air, which air can be obtained from a long length of empty lead pipe having a column of water pressing at the other end or from a pump.

I have now said sufficient about the making and the judging of cocks, I will therefore now explain their uses and names.

Plain Shank, R.B. (Riveted Bottom).

Fig. 1,000 illustrates one of the old make bib cocks. The plug at the bottom is riveted over, which prevents it being taken out or otherwise interfered with, and is suitable for

FIG. 1,000.

places where the cock would be apt to be unscrewed and stolen. This is the class of cock made 1,000 years ago, except the frill round its nose.

I said "1,000 years ago" in one of my lectures some little time ago, and was laughed at by the know-alls all shouting out that they did not cast cocks then, and that cock-casting was of modern date, within 500 years, and such-like twaddle. Of course, I knew that such cocks as Figs. 1,000A and 1,000B were cast by the ancient Romans. How about Vitruvius giving orders that every main pipe that passed through the street should have a governing main cock?

How about Homer in *Iliad XIV.*, writing on valves?

"Touched with a secret key, the doors unfold;
Self-closed behind her shut the valves of gold."

Here is a proof that not only cocks were used, but also self-closing valves.

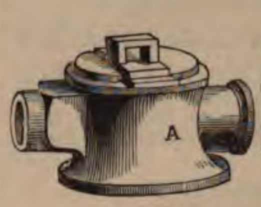


FIG. 1,000A.

FIG. 1,000B.

Bib Cocks, S.B. (Screwed Bottom).

Fig. 1,001 illustrates a plain cock, having a screw at the bottom of the key for tightening up or ground-in at any time should it leak. This is a great improvement over the

FIG. 1,001.

riveted bottom plugs, and the cost is so very little more that it should always be used when and where required.

Square Shank Bib Cocks.

FIG. 1,002.

Fig. 1,002 illustrates a square shank bib cock. It be had with riveted or screwed bottoms. The use o.

square shank cock was to enable the cock to be changed without making a joint before the screw boss cock came into use, which was done as follows :—

Suppose you to have a square socket to fit the outer part of the cock shank. Now warm the shank of the cock and neatly wrap some tow round the same, and with the square bossing iron M, Fig. 12, make the boss hot, then melt some rosin and mutton suet, and pour this on the towed part of the cock to saturate it ; pull out the bossing iron and press the shank of the cock into the socket and hold it firmly there until it is set, and the job is done. To take it out warm it with hot water, or as best you can. Of course, this boss and square shank should be rough left from a good coarse file. This cock was in use in the thirteenth century.

Bib Cocks, S.B. and S.B. (Screw Bottom and Screw Boss).

Fig. 1,003 illustrates a screw bottom and screw boss bib cock. The boss, instead of being square, as in Fig. 1,002, has a, say, ¾in. universal screw for iron pipe thread and for screwing into a boss with a washer. The screwed

FIG. 1,003.

shank cock may be had without the screwed boss. It is then called S.I. (screwed for iron). If you notice the noses of these cocks, Figs. 1,000, 1,001, 1,002, and 1,003, you will see that they are of a kind of square, and have a projection on the top of the nose ; this is known as the frill nosed cock. See the difference in the shape of the nose at Fig. 1,004 ; this is a plain nosed cock.

Full Way Cocks.

Fig. 1,004 is a full way cock. There is a difference between a full way cock and a round way : the full way

FIG. 1,004.

cock has the way elongated up the shell of the cock, as shown at Fig. 1,004, whilst the round way cock has its bore full size and quite round through the key, or as round as the shank of the cock (see Fig. 997), and, as a rule, is a much stronger pattern than square way cocks.

Bow Key Cocks.

This cock is illustrated at Figs. 512 and 1,005. It is used in places where the cock cannot be turned by the

FIG. 1,005.

hand, either through its being too large or too tight. They can be had S.B. and S.B. (screw bottom and screw boss) or S.I. (screwed for iron pipe).

Horizontal Bib Cocks.

These are shown at Fig. 1,006, and are used for butler's pantry or other sinks where the lid of the sink is apt to

FIG. 1,006.

shut down upon the upright cock. These cocks may be had left or right handed. Fig. 1,006 you will perceive to be a horizontal right-handed cock, S.B. and S.B.

FIG 1,007

Fig. 1,007 is a left-handed S.B. and S.B. horizontal hot water cock, with brass spanner; but hot water cocks are often used for cold water, for, as a rule, they are the best ma[illegible] be screwed up tighter for higher pressures [illegible] used.

Fig. 1,008 is an illustration of the horizontal cock without spanner, sometimes used for ball cocks, and, when such is the case, should be knighted, viz., a pin put in the plug, and the shell of the cock being cut quarter way, so that this will only turn quarter way, which prevents the ball from underlocking or drowning itself. The knighting is shown at C, Fig. 1,666.

FIG. 1,008.

FIG. 1,009.

FIG. 1,010.

Fig. 1,009 is a S.B. and S.B. bib cock with spanner.

Fig. 1,010 is a shell pattern full way S.B. and S.B. bib cock with spanner.

I may here remark that these are the best pattern cocks for hot water, having a medium pressure, and may be had horizontal.

Lavatory Basin Ground-in Cocks.

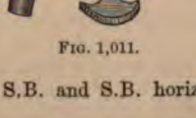


FIG. 1,011.

Fig. 1,011 is a S.B. and S.B. horizontal right-handed basin cock.

Fig. 1,012 is a S.B. and S.B. upright basin cock; and Fig. 1,013 is an urn cock, formerly used for lavatory basins.

FIG. 1,012.

FIG. 1,013.

Also see Hot Water Cocks. as there are a great variety of them.

Valve Cocks.

These cocks are shown at Figs. 1,014 and 1,015. It will be seen that the water-way through the cock is closed by a valve, as shown by the section, Fig. 1,014. These valves are leathered or rubbered on their closing face, which must be renewed every three or four years,

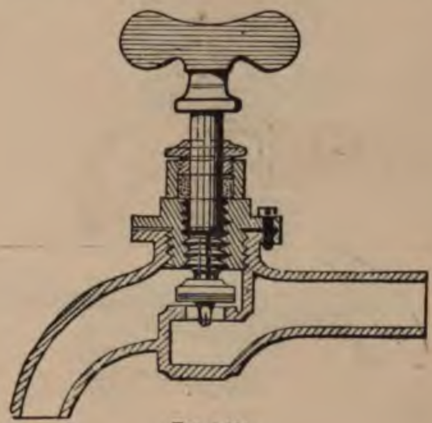


FIG. 1,014.

FIG. 1,015.

according to the amount of grit or dirt in the water, and class of work, or the use of the cock.

Fig. 1,015 is a shell pattern screw-down bib cock S.T.

(screwed for iron pipe), whilst Fig. 1,016 is a shell pattern screw-down bib cock S.B. (screw boss), and Fig. 1,017 is a plain shank and body screw-down bib cock, often made thus for cheapness, &c.

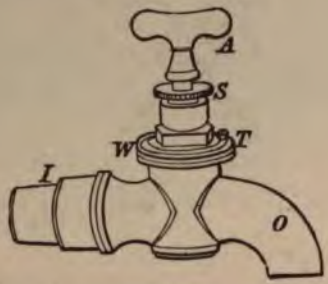


FIG. 1,016.

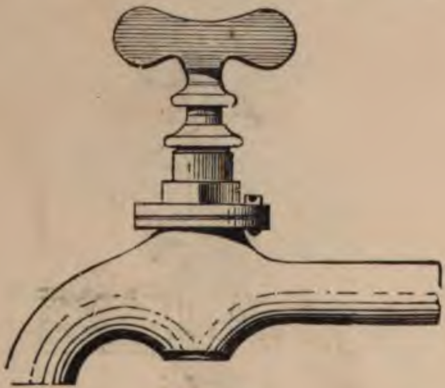


FIG. 1,017.

FIG. 1,018.

Fig. 1,018 is a screw-down stop cock, plain ends, the section of which is shown at Fig. 518. For other kinds of stop cocks, see pages 210, 211, and 212, Vol. I., also Hot Water Work, &c.

Fig. 1,019 is a plain shank, also a square boss, half-turn screw-down bib cock, a section of which is given at Fig. 518.

FIG. 1,019.

FIG. 1,020.

Fig. 1,020 is the same thing S.I. (screwed for iron), and Fig. 1,021 is the same kind of cock with long screw and fly nut for screwing into the sides of the cistern, such as slate

or iron, or for boilers if rubber with wire be used for the valve. There are also special washers now sold by lead and brass merchants for hot water.

Shut-off for Repairing Valves.

At Fig. 1,021 will be seen a very ingenious arrangement in the boss and shank of the cock for temporarily shutting off the supply when the valve is required to be releathered.

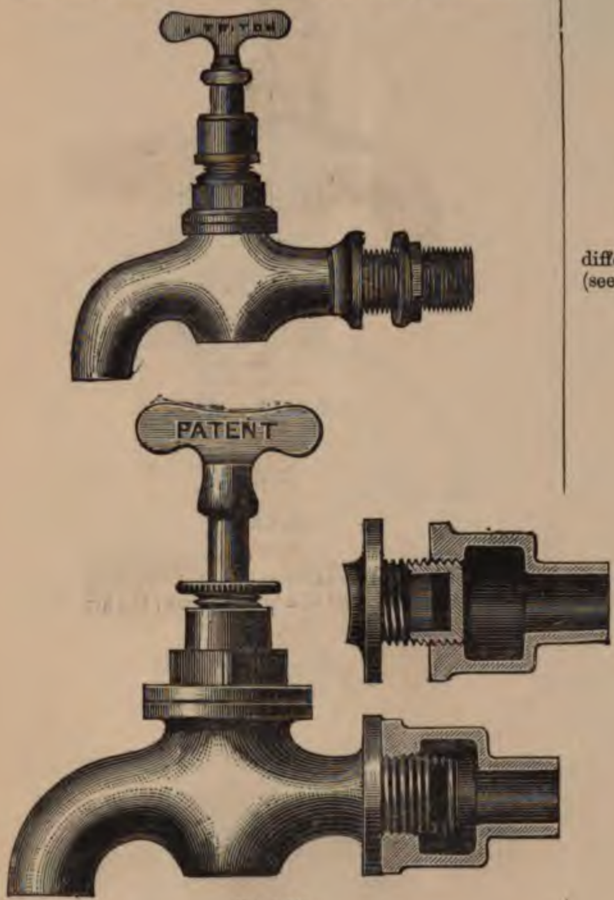


FIG. 1,021.

You, by examining the boss, which is in section, will there see that the unscrewing of the cock brings the disc up against the front, and so the elongated slots in the shank end of the cock are no longer exposed to the water, and consequently the water-way closed.

This is much after the principle of the tube sliding syphon cock mentioned on page 561, Ewbank's "Hydraulics," which dates back to December, 1841, and similar in action to the tube ball valve, Fig. 1,048.

Brighton Pattern Bib Valve.

This is shown at Fig. 1,022. It is very similar in action to the Rotherham pattern bib valve, except that with Fig. 1,014 there is a stuffing-box round the spindle, whilst in the Brighton pattern cock, Fig. 1,022, there is a hat cup leather. I may say these bib or stop valves are made in many

FIG. 1,022.

different ways, some having cup leathers, others plugs (see Chemical Valves, see Cortin's) to close the water-ways.

Duplex Valves.

FIG. 1,023.

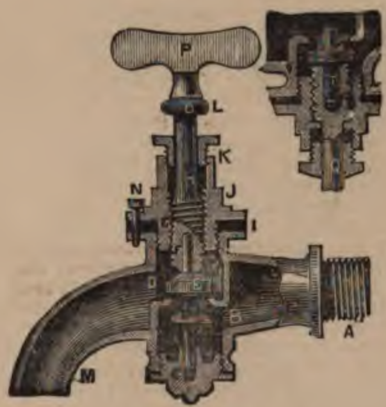


FIG. 1,024.

These valves are illustrated at Figs. 1,023 and 1,024, and well illustrate the method of fixing a valve or plug

for shutting off the water whilst the main valve is being repaired. Also see Fig. 1,024, which may be had bib, stop, or ball valves.

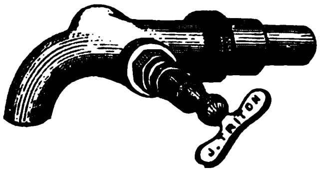


Fig. 1,025.

Horizontal Bib Valves.

These, as may be seen at Fig. 1,025, can be had left or right handed, and need no further description.

Diaphragm Valve Cock.

This cock is shown at Fig. 1,026, and is a valve largely manufactured by Messrs. Lambert. The section of the cock will be understood by reference to Fig. 1,030, which in this case has two diaphragms instead of one. The

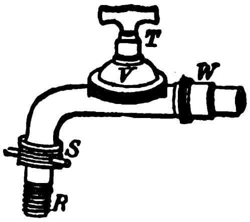


Fig. 1,026.

diaphragm in Fig. 1,026 is fixed between two flanges having the centre attached to the spindle, as at Fig. 1,030. This cock, Fig. 1,026, also illustrates a hose union fixed on its end for shampooing, or a garden supply. Also see Hot Water Cocks.

Waste Preventer Cocks.

The "Waste Not."

There are a large number of these cocks in the market, and by very far the larger quantity are utterly useless, and therefore I shall only give one or two which have stood the test of time and work.

I will therefore commence with the "Waste Not" valve, Fig. 1,027, made by Messrs. J. Tylor & Sons, which will be readily understood from the following description:—

A, Fig. 1,027, is the inlet of the valve; H, the valve seating; K, the valve; F, the piston made to fit into the cylinder G; this cylinder is attached to and actuated by the spindle S. The other parts of the cock are much about the same as those described at Figs. 1,014, 1,015, and 1,016.

The action is as follows:—Suppose the piston valve, F, K, to be down upon the valve seating H; on turning down the cylinder G, which is of quick thread, into the cock, it forces the water from between the top of the cylinder and the top of the piston valve, the cylinder then will be down. Now quickly turn up the cylinder; this, by reason that the *piston valve is made* to fairly fit, will take the valve up with it when the water will run, but as the piston valve is free to descend by water getting above the piston it will do so, and will shut off the water, notwithstanding the actuating cylinder to remain up, and if the piston be a little way out of the cylinder under a strong stream; even though the cock be fixed upside down.

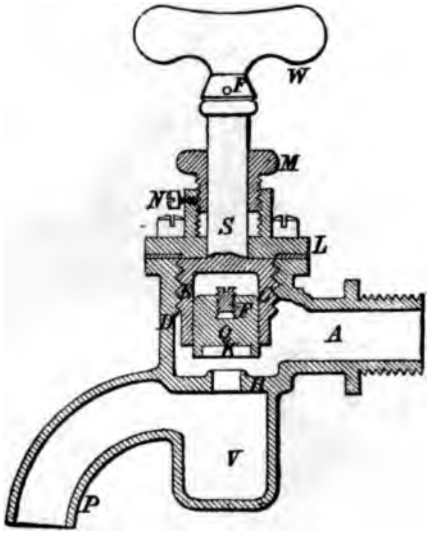


Fig. 1,027.

Fig. 1028 is the same thing, but working with a diaphragm top instead of a stuffing-box; the arrows show

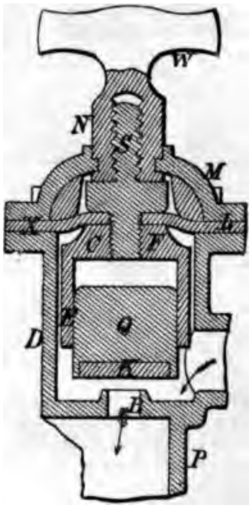


Fig. 1,028.

the water-way. *See* Waste Preventer Valves for Attaching to C[illegible] Pipes, Figs. 561, 562, 563, and *also* "Waste [illegible]igs. 499, 637, 638, &c.

Diaphragm Waste Preventer Valves.

This is Messrs. Lambert's valve, which can be readily understood from the following:—E, Fig. 1,029, is a flexible diaphragm fixed between two flanges, the middle part of which is attached to the spindle K;

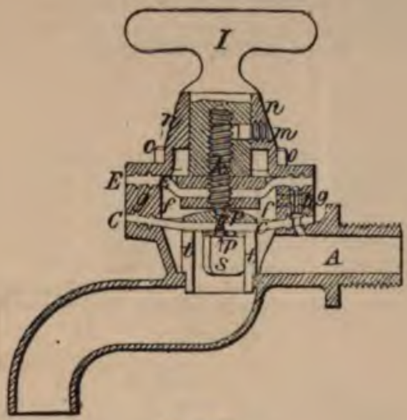


FIG. 1,029.

P, is another flexible diaphragm fixed between two flanges and acting also as a valve. Between these two diaphragms is an enclosed space filled with water, and having a small water passage G. Now the valve is closed. By turning up the handle I it brings up the top diaphragm; this, by the smallness of the water passage (which can be

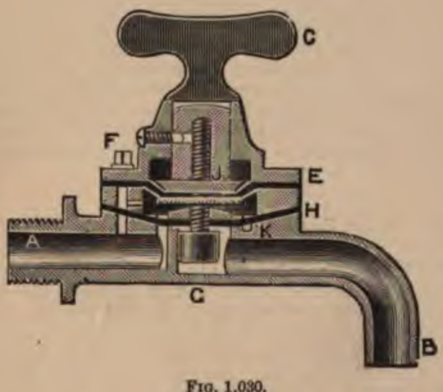


FIG. 1,030.

regulated by the screw F, Fig. 1,030, and G, Fig. 1,029), sucks up the lower diaphragm and opens the valve P, when water is allowed to run; but the water soon percolates through the small passage and again into the space between the two diaphragms, and so the valve is lowered and again closed. (See Figs. 562, 563, 629, 630, &c.)

You will see that the actuating principle of this valve is the displacement of the water by induced current, force, or suction, and therefore that of Fig. 1,027, which may be of innumerable variations.

The Sucker Waste Prevention Cock.

Known as the Frugal Valve, also as the Triton Valve, it being my old trade name and trade mark (see outside of binding). As J. Triton figures in several places in this work, I should say that it is an old disused assumed name, used by myself years ago to distinguish the brass from the lead department, and to prevent jealousy, as plumbers thought I had no right to have two trades.

FIG. 1,031.

This valve is in action that shown at Figs. 618 and 624, &c., and will be readily understood by reference to those figures; the difference being that this valve, Fig. 1,031, has a cup leather at the end of the spindle for actuating. It will be readily understood that by drawing up the spindle it will also draw up the cup leather, and that if a diaphragm be fixed between the flanges that it will follow the cup leather; and should the diaphragm not cover the valve seat as in Fig. 1,029, water will run; but as there is a small hole in the diaphragm it admits water and gradually descends, and so again covers the valve seating. But this does not rest here, the cup leather is made of indiarubber, and as it is pressed down upon the flat diaphragm mouth downwards so it expands laterally, and so forms a boy's sucker, which on its being raised brings up the diaphragm (*or even a piston valve*, as in Fig. 1,027), and holds it there for a given time, when it is released; then the diaphragm slowly descends and again covers the valve seating.

Self-Closing or Spring Valve Cock.

There are scores of self-closing valves in the market, therefore I will just illustrate one or two of such. For this see Fig. 1,032. This is known as the spring valve,

FIG. 1,032.

largely used for wash basins. It is a valve closing with the stream, and is assisted with a small spiral spring. Sometimes this valve is made to close slowly by means of a cup leather, to retard its speed, something like that shown at K, Fig. 533, which may be had at Messrs. J. Tylor and Sons. The self-closing spring valve is also shown at Fig. 1,548, also at PULL, Fig. 1,494, and also in Emanuel's section, Fig. 1,549B, which illustrates the cylinder below the valve for retarding the closing of the valve and to prevent concussion.

Ball Cocks and Balls.

We now come to that part of our work where the water discharges into tanks, and requires very particular attention, for without care the plumber with ball cocks will be always in trouble. You have seen the different kinds of bib cocks, and now know what a plain or square shanked cock is, also what S.B., S.B. means. Now refer to Fig. 1,008, this is a ground-in screw bottom and screw boss ball cock, which had to answer its purpose until the ball valve was invented. When fixing a ball cock fix it in such a manner that when the ball is down

FIG. 1,033.

FIG. 1,034.

it will not lock itself back, namely, bend the stem of the ball at Fig. 1,033, in such a manner that the centre of the ball will always hang 3in. or 4in. on the snout or outlet side of the ball cock, never on the shank side, or the ball will be inclined to drown itself, or to rise the wrong way, namely, towards the side or end of the cistern instead of outwards. Another important point is to fix it in such a manner that it will shut off the water at the proper level, which is 2in. or 3in. below the mouth of the waste or overflow pipe. Be sure never to use a ball cock unless it is knighted, to prevent the plug turning more than the quarter turn.

Water Balls, and Testing Them.

There are various kinds of water balls. Fig. 1,034 is a pressed-up ball; Fig. 1,033 is a plain ordinary ball; the stems or lever part are best made of copper, as also the ball itself; for cheapness zinc, glass, and even wood is used for making these water balls. Some plumbers like the hand-worked or beat-up ball, whilst others like the spun-up shell; such can be bought in the two halves called shells, having "swedges," and are soldered together at these swedges, as shown at Figs. 1,033 and 1,034. Of course, these water balls are fitted on the ball cocks by filing out the eye of the stem with an 8in. square file. Press them hard with the thumbs for their substance.

Testing Water Balls.

Very few plumbers *know how* to test a water ball, not a thousand, nor even is there one in a hundred *manufacturers* that know how to do this. I, however, will now publish this supposed secret to the reader. Get a pail of hot water and push the ball into it; if the ball is unsound or not airtight, the air within the ball will expand and bubble out, thereby putting the water into motion, which is a plain proof that the ball is not sound; it can then be turned about near the surface of the water, and by continually turning it round and bringing the defective part to the top you may find the exact spot of leakage for repairing. This should be practised by every workman, especially in places where a ceiling or two is liable to be washed away by the drowning of a water ball.

Ball Valves.

Of all the fittings connected with plumbing, there is none of so much importance as the selection of an efficient and good ball valve. This should receive the most careful attention of the plumber, for a ball valve suitable for one pressure would be for another utterly useless. I will, therefore, show and describe a few suitable for every class of work. The simplest known is that illustrated at Fig. 1,035. This valve is suitable for low pressures, and

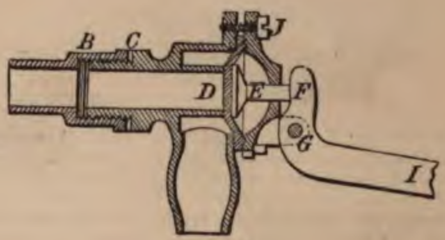


FIG. 1,035.

is simply a plain disc D, covered by a rubber diaphragm E, and held against its seating by the spindle and lever F. J, is the cap for taking off for repairing this valve, &c. This valve, if the seating is reduced to a small bore, say ½in., is exceedingly good for feed cisterns to boilers. This valve has been made to an endless number of different patterns, and to various shapes, many of which have been patented, but are not so good as the original pattern.

Feed Cistern Valves.

This valve is illustrated at Fig. 1,036, which is a section showing the valve shut off, and Fig. 1,037 the section showing the valve when open. It will readily be seen that this valve has no parts whereby the ball can possibly get stuck up, and so rendered useless. This kind of ball valve is also the best kind for reliance to feed cisterns to boilers. Sometimes this valve is made with two forks at E, but I prefer only one, to pass through the centre of the spindle D (the slot of which is shown at W, Fig. 1,036), which, I think, is much better than two forks, because when two forks are used the one may be a little behind or not level with the other, and would thereby cause the spindle to be pressed all on one side, thereby causing the valve to let by; but when the lever of the fork is made as shown at Q, R, the fork presses in the centre of the lever and so pushes the valve fairly against its seating. The fork may be rounded, as shown at E, to work against the flat part of the spindle; or which is

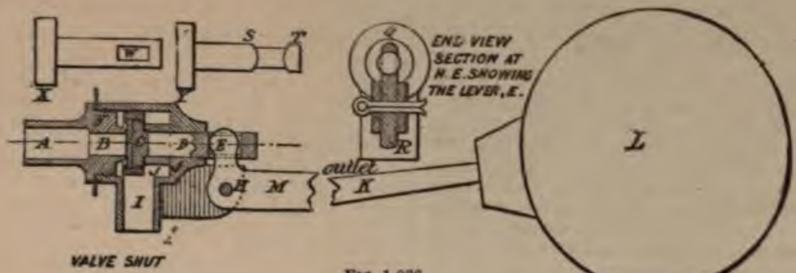


FIG. 1,036.

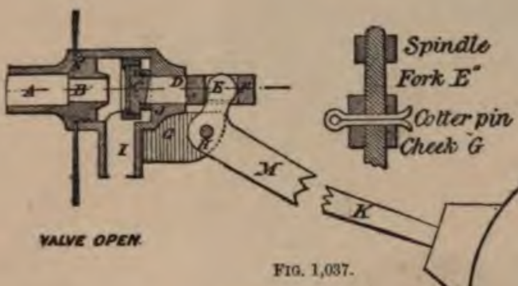
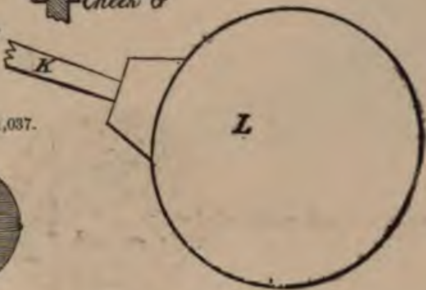



FIG. 1,037.

FIG. 1,038.

still better, the end of the fork may be parallel to work through a rounded bearing in the spindle, as shown at S, T, and W, and in such a manner that the fork, when opening or closing the valve, will always press against the centre of the spindle. I always have this feed cistern ball made with $\frac{1}{8}$in. to $\frac{1}{4}$in. hole seating, which is a double security against leakages, &c. Should the valve not be made to shut dead off, the water will always be dripping, unless an overflow pipe be fixed (which should always be done), and there is likely to be a nuisance.

For ball valves fixed, see the Cistern, Figs. 609, 610, 650, &c.

Fixing Ball Valves.

When fixing the ball valves, see that the pipes are well washed out before screwing on the ball valve, and that there are no lead shavings or dirt under the seating before you leave it, as such will cause the valves to let by the water.

Compound Lever Pattern Ball Valve.

Fig. 1,039 is an elevation of one of these ball valves, and Fig. 1,040 a section. It will be seen that K is simply a disc and L a valve, which is held up to its seating by the short lever D, and, by the pin E and connecting link U, is connected to the long lever at F; G is the pin or fulcrum of the long lever H; M is the spindle for keeping the valve L perpendicular to the base of the seating; and N the feathered guides working middling tight within the cylinder A, P. R is the plan of the same.

The action is as follows:—The water enters at V, passes on and through the seating; but when the valve is closed as shown, the water is upheld according to the power put upon the ball and levers H, D.

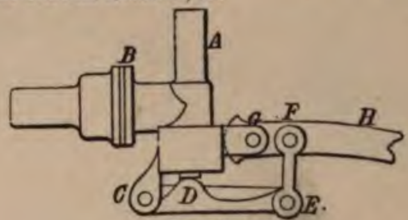


FIG. 1,039.

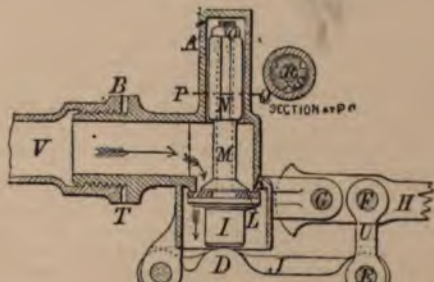


FIG. 1,040.

CAUTION.—When fixing or examining this valve d— —t pull up the ball with much force, or you will s bottom lever or cut the valve rubber, and so r valve useless.

This valve is a nuisance when the water is constantly on, as it is of all valves the longest shutting off, the long lever having further to travel in proportion to the closing of the valve than the lever of any other ball valve.

Singing Ball Valves.

As a rule all ball valves are made with the balls too small, or not sufficiently long in the lever, or that the valve is made to work too loose. When such is the case, they are apt to cause a humming noise, or quite a sing; when this occurs, alter the ball or lever, or tighten the valve. You never hear this with such ball valves as shown at Fig. 1,049.

Stanhope Lever Ball Valve.

This is well illustrated at E, K, Fig. 1,085 (Messrs. Tylor and Sons). It is a kind of lever which gains power as the pressure of water increases, viz., as would be the case in or near the dead point of a crank; or, instead of this, a cam may be used. The "cam" or eccentric action is more suitable for low pressure work.

Safety Ball Valve.

This ball valve is a compound lever ball valve, the valve of which is similar to that shown at I, L, Fig. 1,040, the advantage being, in Fig. 1,041, that the water does not splutter about from coming in contact with the lever as it does in Fig. 1,040. The ball in Fig. 1,041 is pressed up and is very strong.

The ball valve, Fig. 1,042, is similar in construction to Fig. 1,041, the difference being that the valve is guided with feathers and does not protrude through the seating. It has, also, a shield, as at PATENT SAFETY, to prevent any water spurting out in front. For a section of this valve, see the cistern with the valve fixed at Fig. 628.

This ball valve I designed and made by thousands in the years 1870 to 1876, when the second lever was dispensed with: then the valve went by the name of the Croydon Ball Valve, as at B, Fig. 1,042. The shape is now somemodified.

Fig. 1,041.

Fig. 1,042.

B, Fig. 1,042.

Fig. 1043 illustrates the Patent Ball Valve, having a square shank for cementing into a square boss.

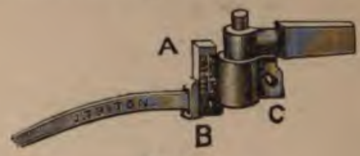


Fig. 1,043.

Equilibrium Ball Valves.

There are various kinds of equilibrium ball valves; some are very simple, whilst others are of a most complicated class, and often without any advantage. For my part, I thoroughly endorse the words which Mr. Muir, the late engineer to the New River Waterworks, once said to me, when in course of conversation, about which kind of ball valves were the best to adopt. His words were: "I like your ball valve, the 'Croydon,' for the simple reason that with it you have only one chance of leakage; whereas, in most others of this class, there are two openings;" meaning that with the class of ball valve, Figs. 1,044, &c., there is a chance of leakage at B, and also at A, J.

The Fig. 1,044 represents by section the ball valve known as Messrs. Lambert's, and Fig. 1,045 is an elevation of the same. It was, in 1870, on account of its price and simplicity, very extensively used, and consists of a cup leather at B, Fig. 1,044, working within a truly bored cylinder. On the top cup leather is a slotted guide for guiding the cup leather and spindle, and for keeping the valve perpendicular with the valve seating, and for actuating the valve and

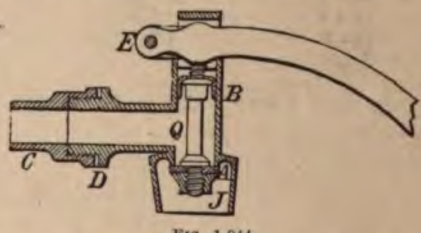


Fig. 1,044.

cup leather; it also serves for the rod to pass through, and to be fulcrumed, as shown at E. The action is as follows:—On depressing the lever, the cup leather and valve J descend from the seating, when, of course, the water is allowed to run past the seating. Now let the ball

float and rise. This will actuate the valve and so bring it up to press against the water, and finally against the seating, and the water will be shut off. At the same time that the water is pressing against the valve so it is against the underside of the cup leather, which tends to push upwards, and by reason of the cup leather and valve with the spindle being coupled together so that as the water tends to force the valve away, it does the cup leather, and as the size of the seating is, or should be, of the same bore as the cylinder of the cup leather, so will the force of the water be equalised, and the whole weight of the two be held *in equilibrio* upon the connecting spindle of the valve and cup leather. In this valve as now made there exists a great evil, and one which may be very easily rectified, at least, in the larger sizes. It consists of the passage Q being left too sharp by the borer when boring out the cylinder part for the cup leather, which should be eased off with a suitable cutting tool, such as a planisher or ripper. Another evil consists of the usually very narrow space round the sides of the valve and the outlet A of the valve seating. Here the dirt, &c., accumulates, and cannot wash away; but if this space were, at least, ⅜in. to ½in. clear, then this valve would have a better chance to work, and the dirt, &c., to pass away. This is especially the case with almost all makers of the Croydon Ball Valve, and is more often to be found in other kinds than not. People will not give the valve sufficient room.

FIG. 1,045.

CAUTION.—When taking this valve out for repairs, &c., be careful not to force the cup leather back with main force, as it will catch in the water-way Q, and thereby get its edges cut and spoilt. When it is found to hang, try and push it back with the end of the pliers, &c., or unscrew the valve off the spindle, and take the cup leather the other way; then, when out, take a sharp-edged reamer, or better, a small ripper (a brass finisher's lathe tool), and ream away the sharp edges round the edge of the inlet water-way Q; then the cup leather will freely pass in either direction. For the ball valve, Fig. 1,044, fixed, see Cistern, Fig. 640.

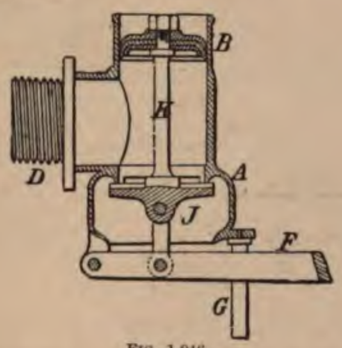


FIG. 1,046.

Fig. 1,046 is the same kind of valve, but worked from below, as at F, G, and is usually used in very large tanks for railway engines, &c.

Ball Valves to close with the Stream.

For this kind of valve, see Fig. 1,047. This valve has its seating set inward, and the valve is allowed to work quite clear, and to leave the water-way fully open and free, which is not the case in Figs. 1,044 and 1,046; besides this, there is another good feature in this valve. The valve lifting upwards allows any small pieces of dirt and stone to pass freely, and therefore is not so likely to be put out of order by such substances. There is one evil in this ball valve. By reason of its closing with the stream, it is apt to be pulled up too suddenly, and so cause a great concussion in the pipes, as in the hydraulic ram, though this act of inadvertence would not happen with careful men, and, as a rule, this valve works exceedingly well. Also see Fig. 647.

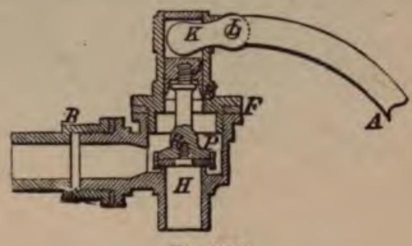


FIG. 1,047.

Movable Tube Seating Equilibrium Valves.

This valve, Fig. 1,048, is made by Messrs. Guest & Chrimes, also by Messrs. Stone and Co., and other well-known brass finishers, and will be readily understood. E is the tube, having a seat formed on its upper edge, which shuts against the rubber D. Round the side of this sliding tube is fixed a cup leather F, which prevents the water from passing the sides of the tube and valve. The action is as follows:—On lowering the lever I, it being coupled to the tube at L, it takes down the tube when the seating comes below the fixed rubber D, and the water is allowed to run down the tube and out at K. Sometimes the valve D is made in such a manner that it is free to move upwards, and can be carried upon the tube seating, which, by reason of its upward movement, will prevent the rubber from being cut should the lever be pulled up too high; but on its descent it cannot follow the tube past a certain mark, which is well shown at Fig. 646. For repairing this valve, Fig. 1,048, unscrew the top C, take out the valve D, and insert the new rubber *of the same thickness*. This valve, as far as being proof against the effects of dirt, &c., is very good, and may be considered a true equilibrium.

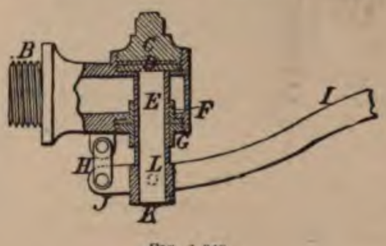


FIG. 1,048.

Horizontal Ball Valves.

These ball valves, *when properly made*, are exceedingly good, and when the valve is made to open its proper width, and the body large enough round the outlet of the valve seating L, Fig. 1,049, the grit, lead shavings, &c., can be

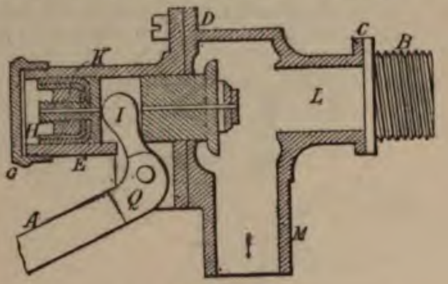


FIG. 1,049.

washed out, and will fall direct through the outlet. This valve, which is screwed for iron, is balanced by the pressure of water being allowed to pass through a small hole I drilled up the spindle, and allowed to get at the end of the piston, as shown at H, where it is prevented from passing out by the cap G, and from getting between the sides of the cylinder by the cup leather K. To repair this valve, simply unscrew the flange F and re-rubber the valve. The cup leather, *in the best made valves*, can be removed by taking out the small screw Q, and allowing the spindle to fall out. Fig. 1,050 is a plain shank.

Some makers make the spindle in such a manner that it will not admit of being so easily taken out, see Fig. 1,050.

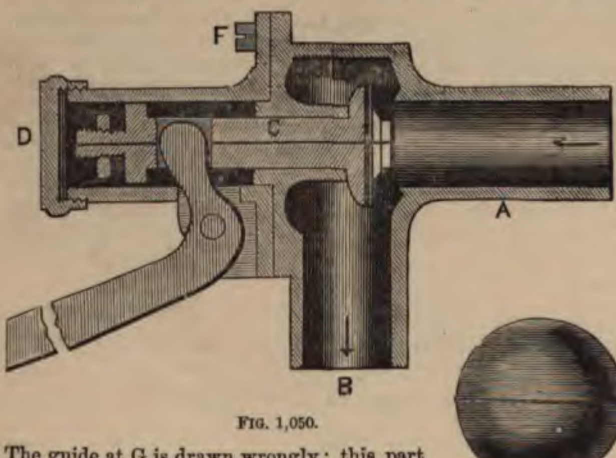


FIG. 1,050.

The guide at G is drawn wrongly; this part should be on the flange F. This also shows

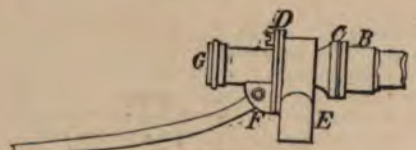


FIG. 1,051.

a badly made valve, there being no room for dirt to get out. When such is the case, a forked screwdriver must be employed to turn the cup leather nut off; then the cup leather can be taken off and the spindle withdrawn, of course providing the lever is unscrewed, &c. Fig. 1,051 is a screw boss and is an elevation of Fig. 1,049 valve, which will at sight enable my readers at once to select this class of valve.

Fig. 1,052 illustrates the valve, Fig. 1,049, made without the large flange.

FIG. 1,052.

FIG. 1,052A.

FIG. 1,052B.

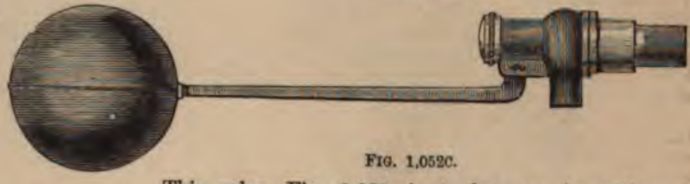


FIG. 1,052C.

This valve, Fig. 1,052, is to be seen in section at Fig. 625, working with a cup leather in a kind of thimble, which preserves the cup leather from injury, &c.; or, at other times, it is made without the cup leather, and depends upon the water ball for closing. I made these in very large quantities in 1873.

Ball-less Stand-pipe Cistern Supply Valves.

By reference to Fig. 628, Vol. I., you can see my patent valve worked by a diaphragm and column of water as follows:—Suppose the main pipe to be full of water, and the cistern empty, the force of water will force up the

diaphragm 79, and so open the valve 81 by the pressure in the stand-pipe 83.

Assume the tank now to be full up to the mouth of the pipe 85. Now, the hydrostatical weight in this pipe is equal, and ceases to force on the underside of the diaphragm 79, and the main force or pressure from the main pressing upon the piston 78, as in Figs. 1,049 and 1,050, the valve 80, Fig. 628, closes by the equilibrium of the water; but as soon as the water in the tank gets below the mouth of the stand-pipe 85, pressure is again exercised upon the underside of the diaphragm, which again opens the valve 80, and so repeats itself.

The opening of the valve depends greatly upon the height of the water in the stand-pipe, and whether the mouth part of this stand-pipe is arranged so that it will fill itself at each action. Of course, the water column pipe 83 and 85 can be taken any height to get the opening or closing action.

Hydrostatic Ball Valve, Fig. 1,052A.

This is the invention of the late Mr. George Jennings, and one that will work under very high pressure with the smallest possible ball. The action is as follows:—First, the little ball at the inlet is a valve *opening* against the pressure, and at the other end of the spindle is another valve, which *closes* against the pressure; C is a cylinder, wherein works the loose piston valve. It will be seen that when the inlet small ball valve is open that water gets up the hollow spindle pipe and into the cylinder C, and presses the cup-leathered piston with the large outlet valve against the seating. Now close the small ball by letting the large copper ball drop; this closes the small ball on its seating, and opens the small valve K at the end of the large cylinder. Now the back pressure of water is released from behind the piston, when the pressure on the front of the valve quickly opens it, and allows the tank to fill, and so on.

Stop Cock Ball Valve, Fig. 1,052B.

There are hundreds of these ball valves in the market; in fact, nearly the whole of the valves hitherto shown have at one time or other had a stop-off arrangement applied. I shall, therefore, only show one, as at Fig. 1,052B. This is a ball valve having a ground-in plug for shutting off whilst the main valve is repaired, or it can be used as a cut-off, and sealed or locked up as required; also see Stop Cock, Fig. 521. Perhaps the best way is to put a stop cock just in front of your ball valve in places where a lot of cisterns come off one large main pipe; this, of course, answers every purpose, and can always be had.

By referring to Figs. 635 and 636 you will there see a tumbler lever kind of ball valve. Such are used in connection with the Barker Mill Water Meters, so that the supply cannot be allowed to dribble in and not register.

What I have endeavoured to do in this, my work, is to place before my readers those valves which are universally used, and by all competent judges accepted as being the simplest and most serviceable for the many different pressures which the plumber has to work against.

My experience, which is over forty years' practical work under nearly all the different large water companies in England, Ireland, Scotland, and Wales, and some in America, teaches me that of all ball valves in the market there are none to equal those represented at Figs. 1,049 and 1,050, *when properly balanced and made*. I write these words in italics knowing it to be a fact that many makers are to be found making these valves who do not understand their business, nor even the principle on which the valve works.

Plumbers' Small Brass Work.—Cistern and Boiler Screws.

There are various kinds of boiler screws, some having long threads, some short, and some with double nuts for screwing up from the outside. Fig. 1,053 is a short boiler screw for iron pipe work. It is first screwed into the

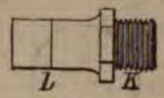


FIG. 1,053.

socket and the joint made at L. At other times this screw is screwed into the side of a boiler or thick cistern, or even

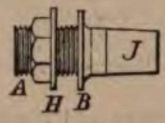


FIG. 1,054.

into an iron socket for connecting lead to iron pipe. Fig. 1,054 is the regular boiler screw, with fly nut H; this screw is used for ordinary iron cisterns.

Slate Cistern Screws.

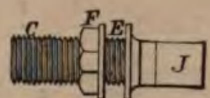


FIG. 1,055.

This is shown at Fig. 1,055, and is used principally for slate or other thick cisterns.

Double Nutted Boiler Screws.

Fig. 1,056 is a double nutted boiler screw, P, R being the nuts. This boiler screw is used for places where you cannot get to tighten up from the inside; P then becomes the

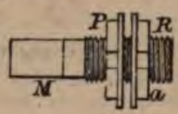


FIG. 1,056.

tightening nut. When selecting this boiler screw, select them with fly nuts of substantial thicknesses. Say for a ¾in. boiler screw, the nut should be at least ⅜in. in thickness, and a 1in., ½in. thick; this gives plenty of thread to the nut, which prevents them stripping, and the screwed

FIG. 1,057.

part of the boiler screw should be well raised, as at Fig. 1,057, which allows extra thickness of metal.

Grummets and Washers.

Grummets are made usually of spun yarn or hemp, soaked in tallow or red lead and boiled oil. They should be made to fit the boiler screw thread.

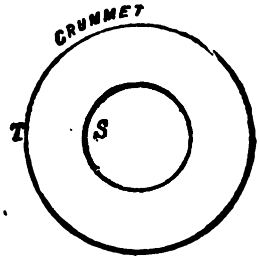


FIG. 1,058.

Washers, Fig. 1,058, may be of leather, rubber, or canvas, old bagging, &c., the latter being well plastered with red lead and boiled oil.

Washers and Wastes.

There are various kinds of washers and wastes for lead, iron, or slate, and other cisterns. Fig. 1,059 is for soldering into a lead cistern.

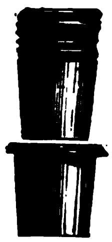


FIG. 1,059.

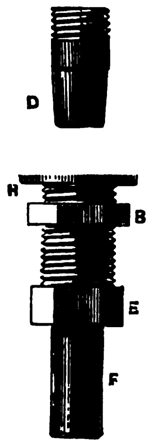


FIG. 1,060.

Iron or Slate Cistern Washers and Wastes.

These are shown at Fig. 1,060, and are used for slate or iron cisterns, and are fixed as shown at S, and also 34, Fig. 1,085.

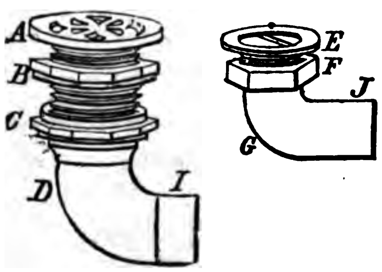


FIG. 1,061.

Sink Wastes.

These are shown at Fig. 1,061, A, B, C. D being one with a strainer, and fly nut and bent union; and E, F, J is one without a deep nut and union, E being a screwed flange, and F the fly nut. Suitable for baths, &c.

Bath and Lavatory Basin Washers and Wastes.

Sometimes Fig. 1,061 is used as a lavatory waste connection, that is when the waste pipe is governed by a valve or cock.

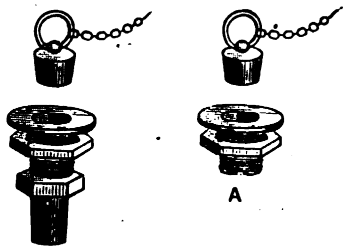


FIG. 1,062.

Fig. 1,062 is the ordinary lavatory washer and plug with fly nut and union. A is the same thing, but without union.

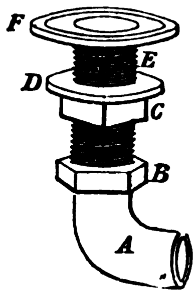


FIG. 1,063.

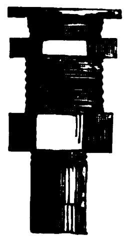


FIG. 1,064.

Fig. 1,063 and Fig. 1,064 are connecting unions for connecting pipes to sides of cisterns, or other odd work.

There are numerous other parts of plumbers' brass work, but it would only be a needless repetition to refer to them here, as they are referred to and illustrated in many parts of this work. For any particular kind of brass work see Index, which will refer to every description of brass work used by the plumber under their proper titles.

I shall now proceed with the practical part of lead pipe laying, and shall begin with the building supply.

I have referred to service pipes from street mains, and at Fig. 960 have given an illustration of the pipe, stopcock, ferrule, and boss, all wiped on, and ready for laying, which may be done in the workshop.

Building Supplies.

(Also see Service Pipes and Mains.)

This is simply a main run, as at Fig. 930. The general plan is to lay the main as a permanent supply for the house, with a stopcock on the premises and near the street; the other end may be carried to a tub, cistern, &c. But on the end, as at L, M, must be fixed a ferrule and screw-down cock, such as shown at Fig. 1,015. Or if a cistern is used, an ordinary ball valve, as shown at Fig. 1,049 or Fig. 1,051, may be screwed or soldered on, as illustrated at K, Fig. 1,085, and at W, Fig. 640. When the main is run, it often happens that a garden or fire-hose supply is required

to be fixed. There are hundreds of different sorts of valves suitable for this purpose, but the one I prefer to fix is that shown at Fig. 1,065, or that at Fig. 1,066.

In Fig. 1,065, at H, may be seen fixed a fire hydrant valve, with hose and cover complete, the section of which is shown at Fig. 1,066, but with a screwed top instead of a flanged one, and will easily be understood. It is plainly to be seen that the valve A is capable of shutting off the

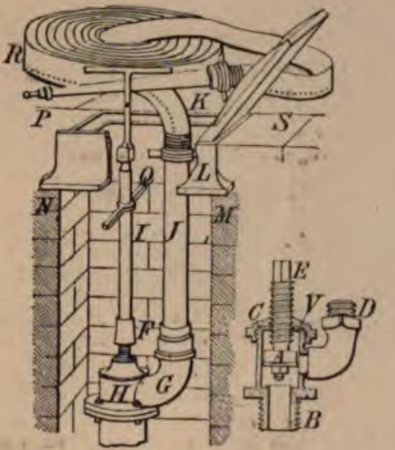
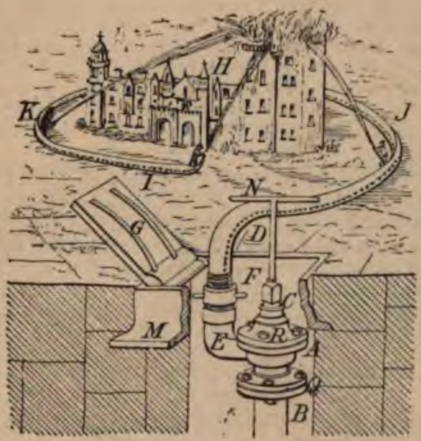


FIG. 1,065. FIG. 1,066.

water, and when screwed up against the top C, that, if the washer V be right, the top part of the valve will prevent the escape of the water through the spindle hole and the sides of the screwed spindle, though some would here use a stuffing-box; but I do not, for the simple reason that when the valve A is shut down upon the inlet seating, the spindle and top hole not fitting too tight, the water will be allowed to run out of the stand-pipe and other parts above the



valve, which will prevent the stand-pipes and top parts of the valve bursting in times of frost. Should the top of the body of the valve be required to be watertight at that part round the spindle, this may be accomplished by the use of the stuffing-box or cup-leather, or by the diaphragm fire hydrant, as shown at R, A, E, B, Fig. 1,067, and Fig. 1,068. Fig. 1,067 also illustrates the method of fixing the same with key and hose in action. On turning open the valve, the water will force open the diaphragm and pass up the outlet E, and into the hose F, D, J, &c., where it may branch off at any number of branches, as shown at I, J, K, &c.

The method of fixing the valve upon the flange pipe B, Fig. 1,067, will be thoroughly understood by the plumber. All that is to be kept in view is to get suitable packing for the bedding between the flanges. I sometimes use felt, at other times canvas, old bagging smeared over with red lead and boiled oil, at other times leather or india-rubber washers. These may be purchased ready made up to any size. I think the last-named is the best when the expense is not studied, and for a superior class of work. I should add that the hose should be fixed on the union F with good strong copper bell wire, not too thick, so that it may easily be bound round. Fold it neatly round, and fix the one end which you commence with in such a manner that the other will overlap it; then bring this end to the part where you leave off, and with your pliers fasten the two well together, or the finishing end may be fastened in the same manner that a scaffolder would tie the ends of the scaffold

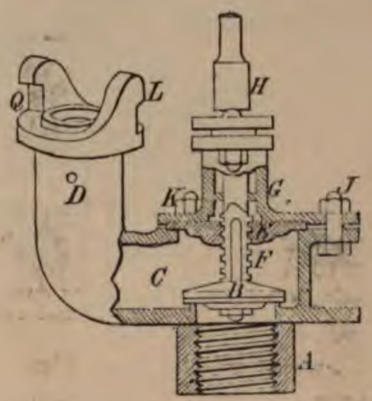


FIG. 1,068.

cords. Fig. 1,068 is a section of the fire hydrant, showing the valve to be of the loose valve kind (as in the Rotherham cock), the difference being the plate E, and round the spindle a stuffing-box with glands. Q holds the lugs of the stand-pipe, and fastens it to the valve outlet, after the method of the bayonet-joint, and is one of the best and quickest methods of fixing a coupling.

Now we are upon the subject of street water mains, we will see how hydrants are fixed and supplied.

Water Cart Hydrants and Meters.

In Fig. 1,069 may be seen the whole thing as fitted up by myself some few years ago. A is the 2in. lead pipe, B the stop cock or a valve, as ordered, or as you please. Q in this case is one of Tylor's Fan Meters. H is the hydrant post as is usually fixed about London; but if the draw cock K is used it should come off a charge pipe, as shown at 2 or at 3, where the valves are above ground.

There are various kinds of meters in the market of late, but the one I have fixed most of is that shown at Fig. 1,070, and known as the Guest & Chrimes', many of which I have fixed within this last thirty years. About twenty-five years back I fixed a large number for Messrs. Jackson & Shaw, builders, of Earl Street, Westminster, including those at Brixton, Peckham Rye, Queen's Road, and other railway stations, also those to supply the Royal Academy, Piccadilly, London, and many of the Metropolitan and District railway stations, all of which, on a recent inquiry, I found to be in good working order. Another I fixed in 1863, at Corunna House Laundry, Hammersmith, which is in good working order.

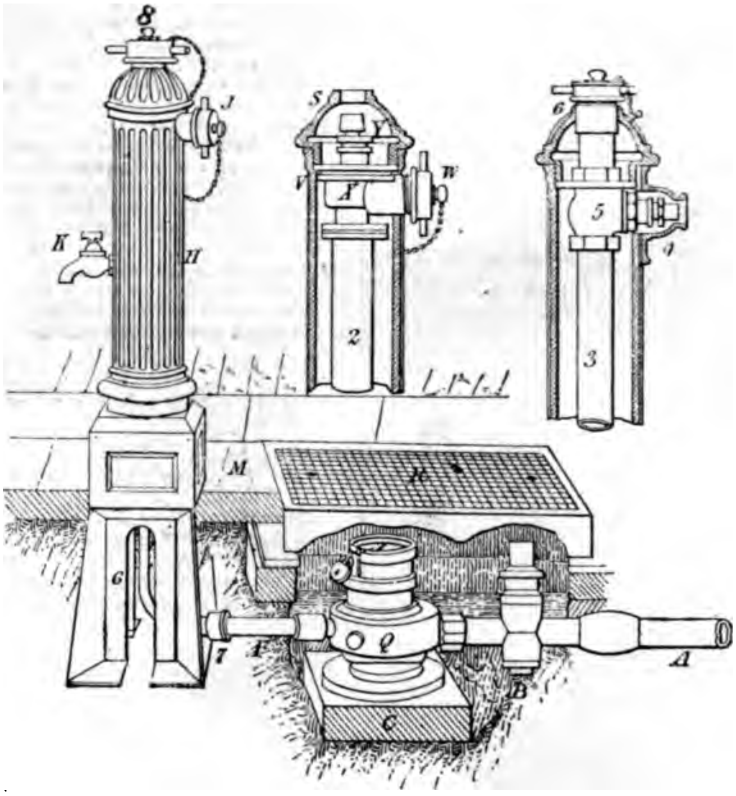


FIG. 1,069.

I have here shown a plug stop-cock in Fig. 1,069 because I fixed this class of stop-cock at the before-named railway stations, which for this purpose stands well, though now the screw-down kind is generally enforced. When fixing these meters as shown, carefully protect them from the frost. Cover the dial with a plug of hair felt, in shape something like an ordinary pen wiper, and at F, or where most practicable, fix an emptying cock to empty the pipes. H, J, Fig. 1,069, is the before-mentioned hydrant, which we will now call a street standpost; the water is supplied by meter or otherwise. When the water is on constant, the shut-off valve, to supply the water to the standpipe, may be fixed as shown at the section 5 and 4, which in this case allows the standpipe to be screwed on the firehose cap 6; but when the firehose is required to come off the side, as at W, J, shown in the section and elevation, the valve is generally fixed as at X, Y When these valves are fixed as shown, the standpost generally stands charged for the purpose of supplying pails, &c., as at the cock K; hence one reason why we call it a standpost.

When such cocks are fixed, they should be of the class known as waste-preventing cocks, a section of which is shown at Figs. 1,027 and 1,028.

Water Meters Registering with Air.

Should you open the reaction meter stop valve when air is within the pipes, these meters will whirl round at a most alarming rate and kick up a terrible noise. There used to be one at the foot of Muswell Hill that has startled me more than once; goodness knows how fast they register on the dial.

It should be known that these meters will not register with a very weak stream, say a crow quill passing through

a ¾in. meter; hence why the West Middlesex Company has enforced a tumbler kind of ball valve, similar to those shown at Figs. 635 and 636.

Positive Water Meters.

Figs. 1,070A and B show section and elevation of Messrs. Tylor's Positive Meter, which operates on the duplex principle, so that it gives a perfectly regular motion to the dials, and without any great perceptible retardation or irregularity in the flow. In this meter there are two pairs of parallel

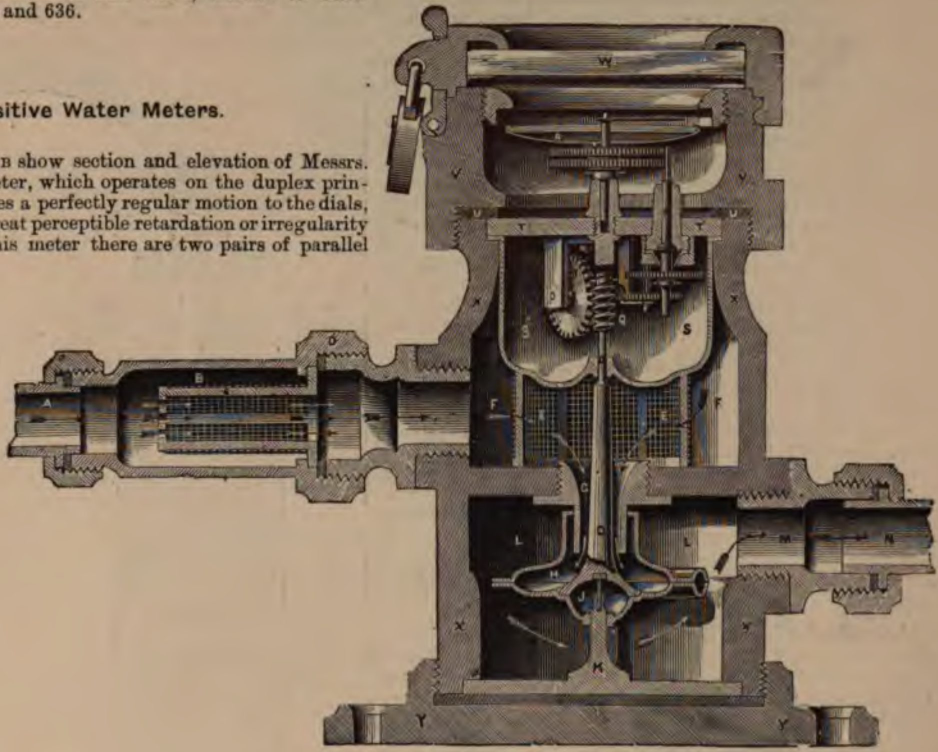


FIG. 1,070.

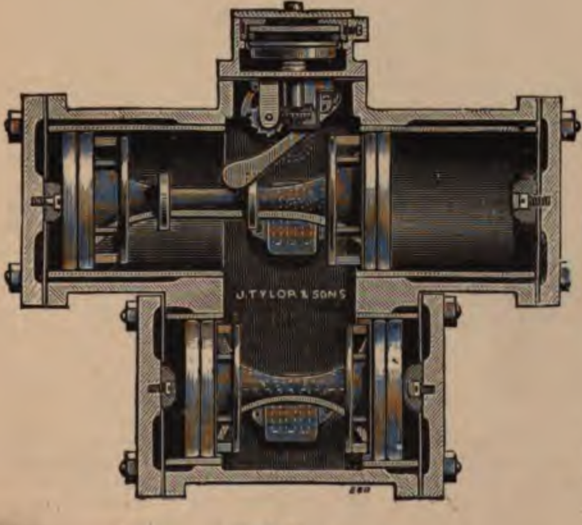


Fig. 1,070A.

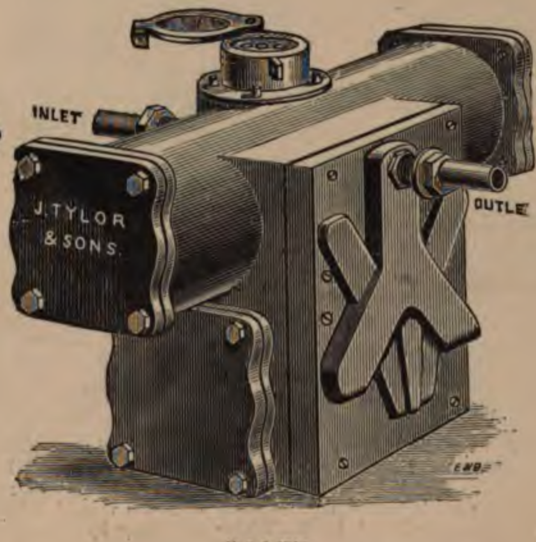


FIG. 1,070B.

cylinders, as may be seen in the section, and within these cylinders, are double pistons, connected by the ⪤ shaped rods, on which are to be seen tappets. These tappets are for the purpose of operating the valves, the upper being a slide valve for the lower cylinder, whilst the lower piston works the upper. The lowest piston's duty is to make as short a stroke as possible, and is in reality the actuating part, which gives life to the measuring pistons above. The water enters through the usual strainer, and from thence to the slide valves and pistons alternately, and is exhausted through the centre of each valve. The index at the upper part of the meter is actuated by the tappet and communicates with a ratchet wheel. The spindle is fitted with a worm engaging with the usual worm wheel and spindle, which works through a water-tight plate similar to that shown at T, Fig. 1,070. The accuracy of this positive class of meter must be nearer the mark than any meter working upon the principle of the Barker Mill, especially when the work is being done slowly, and more than one waterworks' engineer has given testimony that this meter will register within about 5 per cent. one way or the other.

There are various kinds of positive meters in the market. One, Kennidy's, is a very good one, and one which I fixed at the Oil Mills, Hammersmith, for Messrs. Pinchin and Johnson, has worked very satisfactorily for this last ten years. These oil mills are now the Malting Houses, Hammersmith.

Water Meter Providers.

As a rule, the Water Works Company insists in supplying the water meters, and charge a rental for the same; therefore, the onus of keeping them in repair rests with the company, and should they cease to register a supply, then it becomes an acknowledged trade rule to take the average

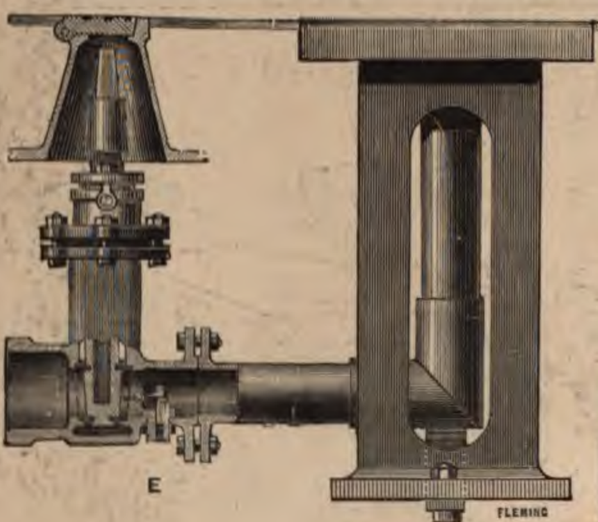


Fig. 1,071.

amount of the present quarter with that of the previous year, except in cases of frost, when the meter should be taken as the index registered; but the complaint of no water (which would be the result of frost) should be at once communicated to the Water Company by a proper registered letter to prevent contradiction.

Fig. 1,071 illustrates a stand-pipe and post complete, made by Messrs. Stone. There is a small emptying valve E, which renders it first rate in frosty weather, and the whole is very compact and complete. The base, B, of the fluted column and outlet stands on top of the base A on the left, which completes the figure.

Fig. 1,071A illustrates Messrs. J. Stone & Co.'s Hydrant Fire and Sluice Valve fixed complete. The excellence of these valves are so well known to water works' engineers to need no comment from me. It can be had fitted with frost valve as shown on the right of the engraving. The spindle is supplied with both stuffing box and cup leather, and altogether is a first-class article, and largely used.

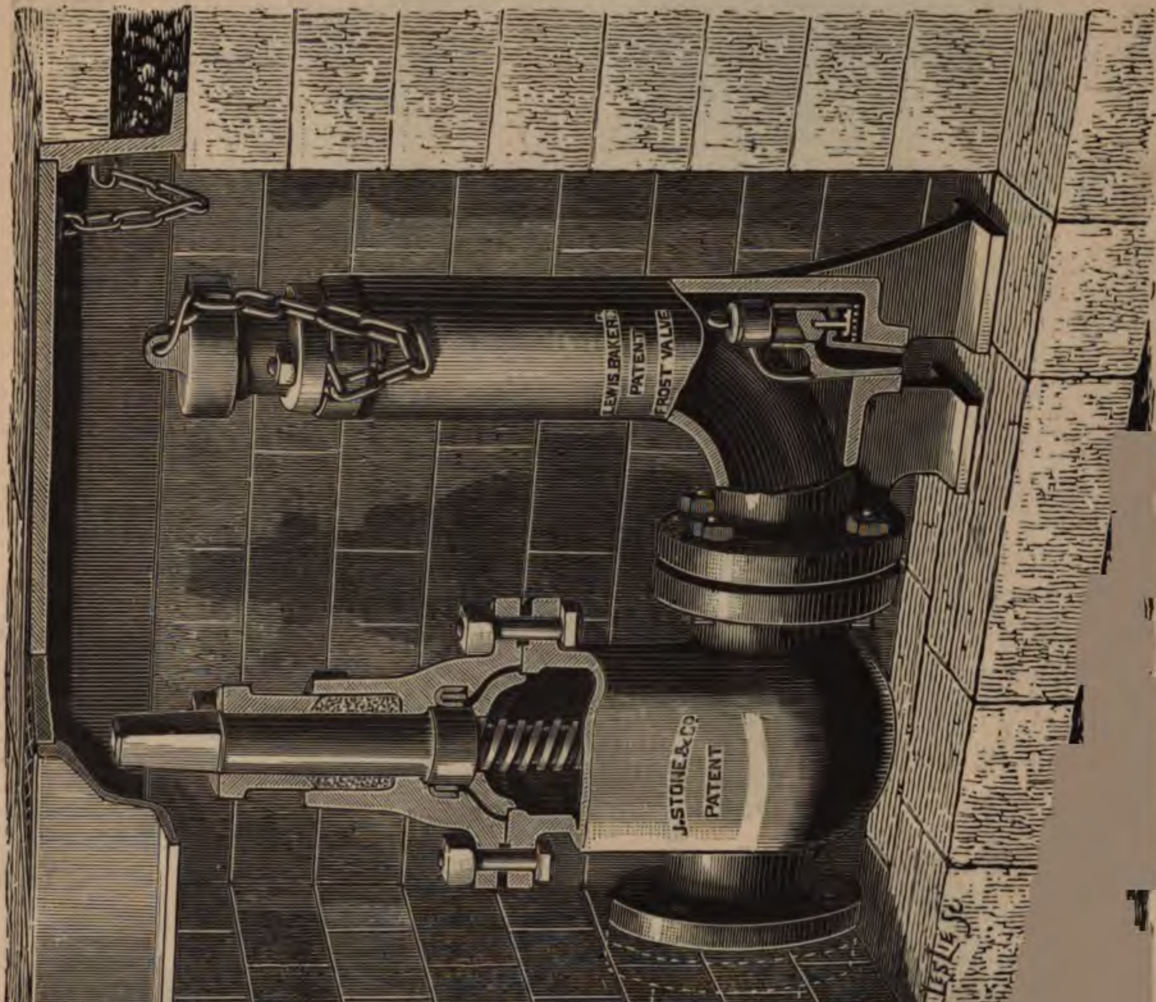
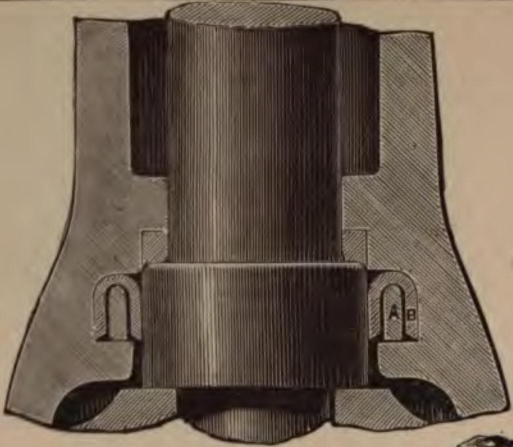


Fig. 1,071A.



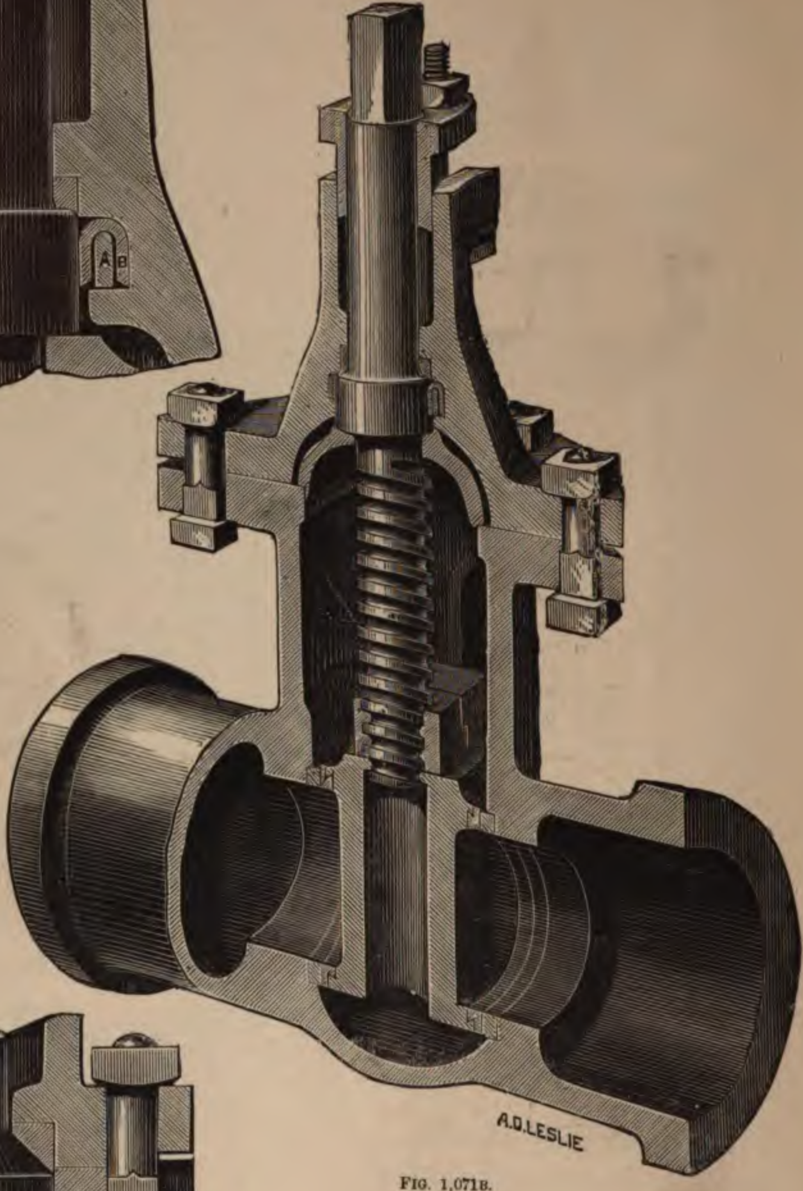


FIG. 1,071B.

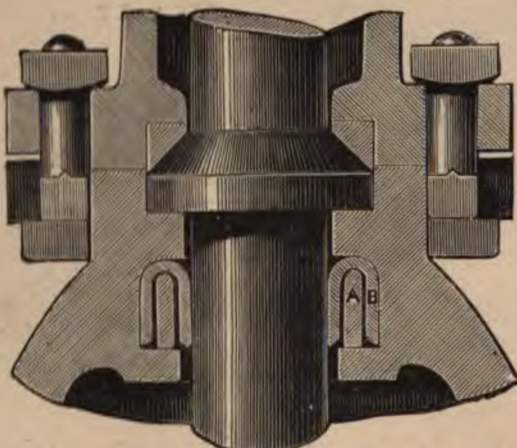


Fig. 1,071B is Messrs. Stone & Co.'s full way Metropolitan Patent Sluice Valve, showing the cup leather, A, B, to save expense of repacking. This valve is fitted with bronze spindle, and the valve face is unwearable, and if used for very high pressure will last many years without attention.

A GUN METAL SPRING RING
B HYDRAULIC LEATHER

FIG. 1,071C.

Drinking Fountains.

(Figs. 1,071C and 1,071D.)

Now we have hydrants in hand I will give an illustration of drinking fountains which are figuring about the streets of London, generally painted red, and reminds one of seeing the children scrambling for poppies in a field of corn. After what I have said on hydrants and the like this diagram explains itself, excepting that in some cases the waste therefrom goes to supply drinking troughs for cattle, dogs, &c. I may add that the first of these London fountains was erected on Snow Hill in the year 1858, and to-day, the association which caters for man and beast in

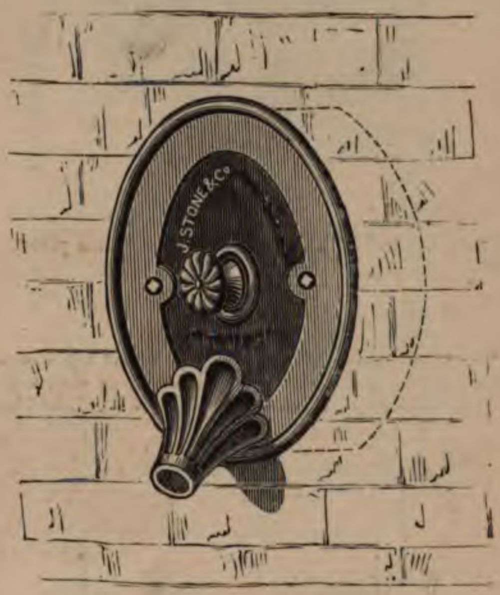


FIG. 1,071D.

this respect, has erected and maintains 700 fountains for human beings, and over that number of drinking troughs for cattle, in the streets and open spaces of London. Of course, I must not be understood to imply that this fountain was the first erected in London, for drinking fountains were in existence in London at least hundreds of years before. Generally speaking, the pillar on the left works with a simple spring valve, P, Q, R, Fig. 500, whilst that on the right shows a fountain to open valves like a door handle, as shown at Fig. 1,071D (made by Messrs. Stone & Co.).

Fig. 1,071E is a fountain suitable for fixing in walls, for public-houses, and for cabmen's shelters, for strong usage.

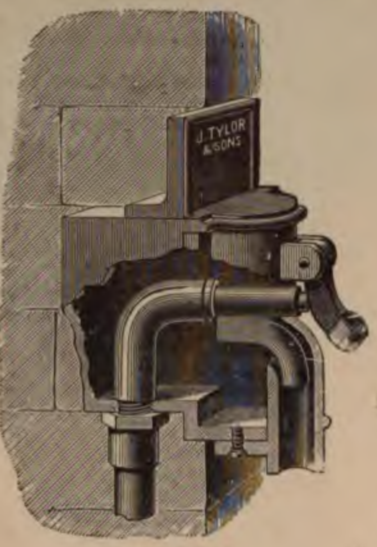


FIG. 1,071E.

It may be had of the self-closing or waste preventing class.

Surface Covers.

The stopcock or hydrant valves when fixed below ground should be protected with a proper cover, as shown at R, Fig. 1,069, Fig. 1,071, and also at Figs. 1,072, 1,073, &c.

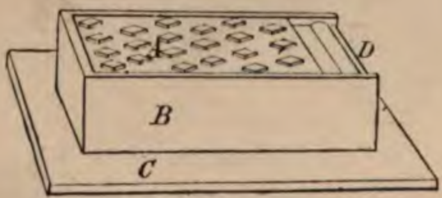


FIG. 1,072.

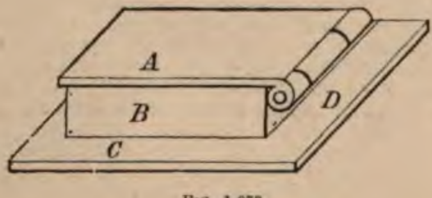


FIG. 1,073.

The former is one made by Messrs. J. Tylor & Sons, and is used in many parts of London. In this the lid (also see A, D, Fig. 1,072) shuts below the top edge of the box, and of this I do not approve, because in the winter, when the frost is about, it gets frozen down. To obviate this evil see Fig. 1,073. In this diagram it may be seen that the lid

FIG. 1,074.

shuts down fairly over the box part, and therefore dirt or frozen water cannot hinder its opening at any moment. Fig. 1,074 illustrates a deep surface cover marked F P (fire plug).

Ferrule Covers.

Fig. 1,075 is an ordinary cock or ferrule cover for placing over top of ferrule, &c., in the street, and in such places where the earth is thrown over the same. The opening B is to receive the pipe or neck F, at Fig. 962; or for a stop-

FIG. 1,075.

cock there are two openings, as at B, Fig. 1,075. When this cover is used, the cock and pipe should be, with hay, &c., properly protected from frost.

Fig. 1,076 illustrates at 4, a surface cover and valve combined. The valve in section is similar to that shown at Fig. 1,068.

Stand Pipes.

Fig. 1,0' [illegible] a hydrant stand pipe for hose, having a [illegible] the top end, the valve part

is in section the same as that illustrated in the cock section, Fig. 1,014, and also in Fig. 1,068.

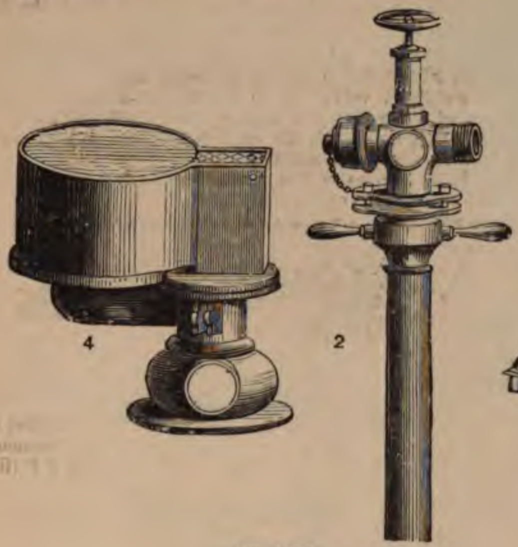


FIG. 1,076.

Stand Posts and Waste Preventing Fountains.

Fig. 1,077 is Messrs. J. Tylor & Sons' Patent Waste Preventer Fountain.

This is largely used for water supplies to cottages, courts, and poor localities. It closes immediately the

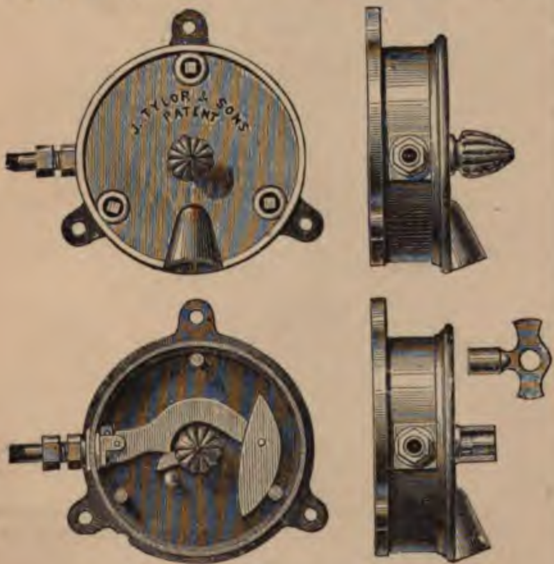


FIG. 1,077.

handle is let go, the handle being so constructed as not to be capable of being tied up or kept open in any way. The case is put together with counter-sunk square-headed screws, which require a key to undo, so that the apparatus cannot be tampered with. The apparatus is also constructed so that water can only be drawn by persons possessing a key, of which any number can be had. The latter system is often adopted, and still further reduces the possibility of waste. The apparatus is fixed against a wall or to blocks of wood in places where a wall is not available.

The apparatus is also well adapted for a drinking fountain, and for factories, or where a number of persons are employed.

Patent Stand Pipes for Frosty Weather.

These are illustrated at Fig. 1,078, and are for the purpose of drawing water from the London street mains

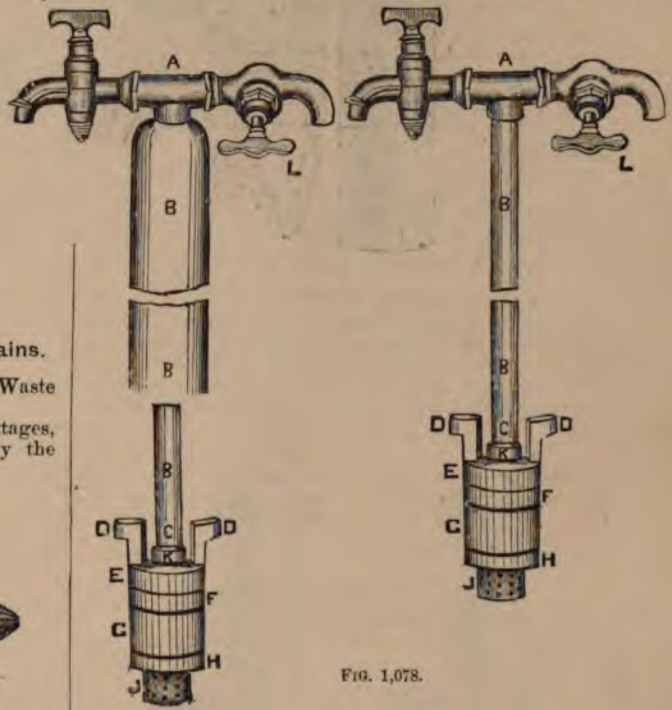


FIG. 1,078.

when the house or other service pipes are frozen. The watermen should carry them round their district and fix them in suitable places for the convenience of the inhabitants.

Fire Plugs.

The mode of fixing these standpipes is as follows:—First (by unscrewing) draw the fire plug, Fig. 1,079, from the fire plug socket, which is simply a cone-shaped hole about 2¼in. in diameter on the top of the main; then take Fig. 1,078 and place the piston H, F (which is made partially of india rubber) into the socket, and the bottom part of the piston H being made of lead fits into the before-mentioned socket. Now, by turning the cocks and spindle B, it, by a suitable screw, causes the flanges H and E to appro[ach] each other, and so compresses the india rubber was[her] laterally, when it holds according to the amount [of] tightness which you give by turning the cock spindle.

On the left-hand side, Fig. 1,078, is the same, but having a wood or other warm jacket B.

FIG. 1,079.

FIG. 1,080.

Landing Hydrants.

Fig. 1,080 is a hydrant used inside buildings with the hose cap below the valve wheel, suitable for landings, &c. Here it will be seen that the whole is of very simple construction, and may be simply bolted on to a flange coming off a main supply, and nothing more can be better.

FIG. 1,081.

FIG. 1,082.

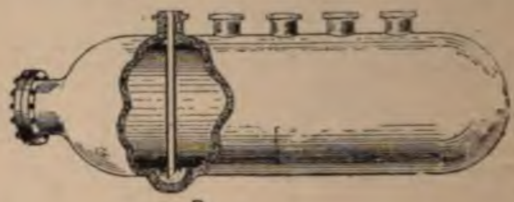
Standposts for Courts and Alleys.

(See Waste Preventers. Also see Figs. 1,071A, 1,077, 1,082, &c.)

Fig. 1,081 illustrates a standpost of the waste preventing kind, the action of which is of the sucker valve kind, as shown at Fig. 618, the difference being that the sucker lifts a weighted valve, which is weighted against the pressure of the water, and of all waste preventing standposts it is unquestionably the most simp e and one of the best lasting ones in the market.

Fig. 1,082 illustrates the same standpost, but with a handle for actuating at the side.

These standposts are also made for fixing to walls, &c.



R

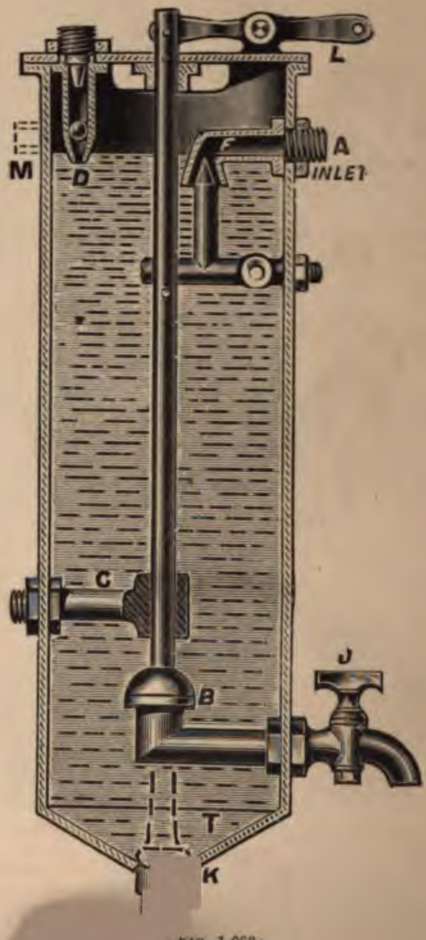


FIG. 1,083.

Cylinder Tanks and Cisterns.

Fig. 1,083 is the cylinder tank and waste preventer cistern as made some years since to do away with the ball valve, and for places where the cisterns do not get proper attention. This is nothing more than a strong cylindrical or other shaped tank, of the circulating hot water tank kind (see Figs. 1,499, 1,578, 1,625; also Water Eggs, Acid Eggs, &c.).

A, is the main supply; D, a floating or other air valve, preferably made of wood or india-rubber, working within a guide; J, a draw-off, which by piping may be taken to any convenient place. This is all that is required in the ordinary course of things.

B, is a waste preventer valve; G, a guide; C, a cup leather; L, the lever; K, the cleansing plug, cock, or pipe.

The action of it is almost too simple for me to describe. The water coming in at the inlet fills the tank and floats the ball D up against the slating, which closes the air valve, as is the case with the ordinary street air valves, and the whole becomes charged when the draw-off becomes under heavy pressure, which in several places I have arranged the draw-off to work under a low pressure, which at times is an advantage. It will be noticed that when the water is cut off and the draw-off cock J open, that water will be allowed to run out, as does the water in the street mains, by the valve D dropping, and giving air to the internal part of the cylinder; the parts above C will always contain air.

The Water Egg, R, is too well known to require any further description.

Double Valve Standposts.

These kinds of standposts are shown at Fig. 1,084, and are largely used, their action being simply that of the

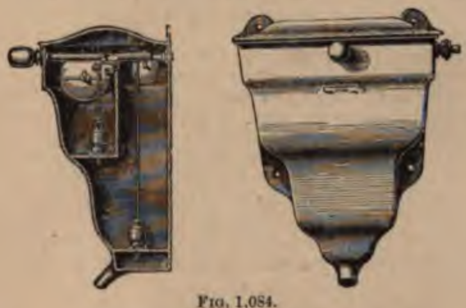


Fig. 1,084.

waste preventers shown at Figs. 645, 648, 654, 655, 656, 657, 658, &c., and need no further comment, excepting that they should be fixed in sheltered places from frost, &c.

Having now introduced to your notice some of the best valves and standposts often required on your mains, the way will be clear for the general plumbing work.

Running Lead Water Mains.—Remarks.

We will now suppose that the walls of the building are up and roofed in, and ready for the inside plumbers' work, and begin with the main supply pipe.

Having the building supply, as at Fig. 960, already laid, suppose we begin by connecting or making a joint, as at J, Fig. 960. Now continue to fix or run your pipes with suitable wall hooks or ear tacks in well arranged chases, and well sheltered from the frost, taking care not to run them more than possible over ceilings or places where, if they burst, they will greatly inconvenience the inhabitants. These great troubles are often brought about by the clownishness of would-be workmen. Then I have seen the main pipe often very much damaged by driving the head of the wall hook half way through the lead, or the pipe reduced in the bore by bad "dents" from the head of the hammer, or badly made bends, crooked lines of pipes (see Fig. 669), the joints half full of solder, stones, and such like, which is often the cause of great hissing or rumbling noises in the pipes when the water is running, especially under high pressure. Always take the greatest care to avoid the above evils, and to fix your pipes so that it is something to be proud of when finished. But, of course, I do not say that you are to be a week doing a day's work polishing or tittivating, or messing away your time, and I shall expect the work done well, with good finish, in reasonable time, in order to compete with others.

Now, having all arranged as at Figs. 339 and 340, let us run the lead pipe as at J, Fig. 960, to M, Fig. 340, and make the necessary joint with a good stop cock and emptying cock, easy of access, and, if possible, exposed to view, and in large establishments with the words printed WATER MAIN STOP COCK.

I do not think more should be written on the *Remarks* of pipe fixing, as they are sufficiently heavy to impress the evils of bad work upon the intelligent young workman, who, of course, would scorn—or, at least, feel very uneasy—to do bad work under any circumstances. Therefore, I shall content myself that anyone reading the Remarks will be ashamed to give innocent people the before-mentioned troubles through their neglect or laziness, or by listening to the advice or persuasions of the jerry builder, bad architect, &c.

Mains.—Cisterns, and Fitting Main Supplies

(continued).

Having gone through the whole paraphernalia of running the service pipes up to the stop cock, we may conclude that the other part of the service pipe between the stop cock and cistern needs no further description, the simple points being to run it as straight as possible, but with easy bends to prevent noise, and protected from frost, and fixing a stop cock in a come-at-able and conspicuous place, with a draining cock just on the house side of the stop cock for taking water therefrom or emptying your main in times of frost, or for repairs, &c.

I will now assume that we have arrived at the top of the cistern, and ready for the ball cock. Let M, Fig. 1,085, be the main pipe. Here we require a branch joint, but before making this branch joint knock over the end of your pipe, which is best done as follows:—

Knocking Up the Ends of Pipes.—First rasp, tapering the end of the pipe for ¼in. from the point downwards, similarly to that shown at J, F, Fig. 111, then with your mallet or small hammer knock the end over nice and regularly until it is closed nice and square, which should be wiped or copper-bitted over; then make your joint as directed in our Joint Making (see page 85, Vol. I.), and fix your ball cock as shown at K, Fig. 1,085; or, instead of making a branch joint, a round joint may be used, as shown at L, Fig. 960, also at 41, Fig. 339, or at 61, Fig. 628.

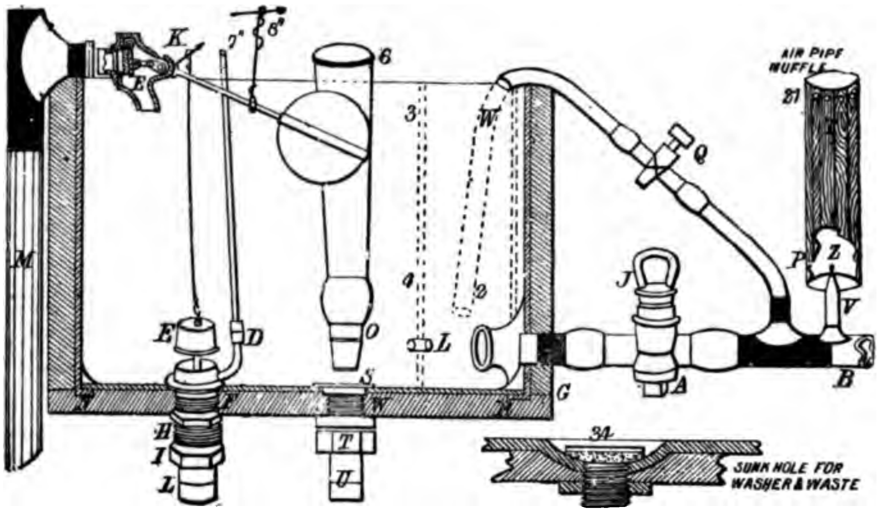


FIG. 1,085.

Cistern Fitting.—Wastes, Outlet Valves, &c.

We have seen how the main or service pipes are run, also how to line a cistern, and now it is time to look after the fitting up of the cistern. For this, examine any of the cisterns fitted such as are shown at Figs. 96, 314, 316, 330, 339, 477, 480, 492, 511, 566, 592, 596, 597, 598, 604, 605, 611, 613, 616, 625, 626, 628, 640, 645, 667, and 1,086. By carefully looking at a few of the above cisterns, you will see a variety of work most likely suited to the circumstances of the case, which at all times are important points to keep in view, for that which will suit one job may be utterly useless for another.

WIPING-IN WASHERS AND WASTE.—Let us now examine the [illegible] work at Fig. 1,085. In this cistern we have three outlets: S, T, U is for the waste. Here in this cistern we should use the washer and waste Fig. 1,059, and before the cistern is lined the bottom should be sunk to receive it, as shown at [illegible] Fig. 326, and as at 34, Fig. 1,085. This allows the [illegible] washer to be screwed in, or, better, wiped [illegible] the surface of the bottom of the tank. Some [illegible] prefer to screw these washers in, but I prefer to wipe them in. When wiping these washers in (shown at Fig. [illegible]) [illegible] the flange of the washer; then [illegible] paper, to fit truly level with [illegible] prepare the lead for receiving the washer. [illegible] flange over the lead pipe at [illegible] the flange of the waste, as is [illegible] W, [illegible] Fig. 330, and wipe a joint similarly to [illegible] and with good [illegible] waste may be used, as [illegible] S, Fig. [illegible] is unnecessary expense and [illegible] washer and waste Fig. 1,059 [illegible]

[illegible] with drains, soil [illegible] between [illegible]

[illegible]—The [illegible] from cisterns [illegible]

shown at K, E, Fig. 1,085, and also at F, B and A, S, Fig. 1,086.

Air Muffles.

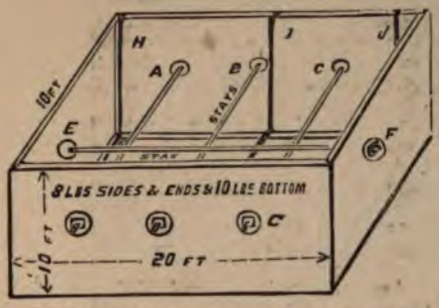
(P. J. DAVIES's Patent. See Figs. 650, &c.)

When fixing pipes leading from cisterns, as at E, Fig 1,085, an air pipe should be used, as at D, to allow the water to drain out of the pipe when the valve is to be closed. But when these air pipes are fixed, great care is necessary to make the pipe where the air pipe is branched into two or three sizes larger than the remaining part of the down pipe, or the air will interfere with the delivery of water through the pipes, unless a small stop cock is fixed on the air pipe, as at Q, Fig. 1,085.

The use of this stopcock on the air pipe is to prevent the entrance of air from passing through the air pipe when the water is rushing down the pipe B, because, if the air is allowed to enter the pipe, it greatly interferes with the full quantity of water being, by the air in the cistern, forced through the short length of pipe at G, by reason of the air being allowed to enter the pipe B. This is only reasonable; for the air, by its additional fluidity to that of water, will be better able to rush into the pipe B, than water through the horizontal pipe L, G, A to supply the partial vacuum occasioned by the weight of the falling water.

Air-Pipe Muffles.

Instead of this second cock Q, if the end of the air-pipe be hammered up, and a *needle*-pointed hole be left in the end, as at J, Fig. 577, this will, to a certain extent, answer, because it only allows the air-pipe V to fill slowly, and to empty accordingly; but it should be remembered that if this hole be ever so small, the water will quickly leave, or a ½in. pipe would soon empty, and air will enter the pipe B. To finally get over this, and to make certain that air will only in *due time* enter the pipe without attention when the cock J, is turned off, make a piece of, say, 8in pipe, as at P, *nearly* closed in at the top (to keep the dust out) and branch a short piece of ½in. pipe with its end *nearly* closed, as at Z, into this pipe, so as to prevent the water entering the stand-pipe too fast, which will also prevent its r[illegible] under the pressure of the atmo-



Burnt Joints, 12,000 Gallon Lead Tank, $\frac{3}{8}$in. thick.

TO SHOW STAY RODS.

Personally made by P. J. DAVIES for Messrs. Pinchin and Johnson, at Hammersmith Oil Works.

Since making these tanks I have made some at the Atlantic Wharf, Bow Common, for storing Oil, 80 ft. by 20 ft. and 20 ft. deep.

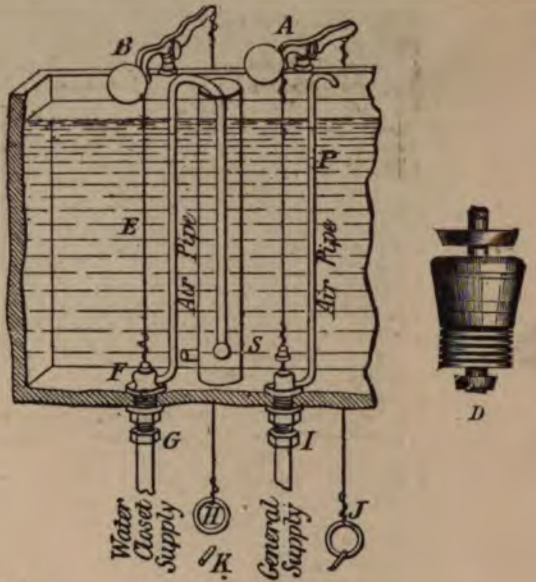


FIG. 1,086.

sphere when the stopcock J is shut off. The top and bottom of this 8in. muffle pipe should be fixed level with the top and *nearly* level with the bottom of the cistern, so that the muffle pipe will hold sufficient water to allow for the *longest time during which water will be likely to be drawn through the draw-off pipe*. Or instead of a long piece of 8in. pipe, a shorter one, whose diameter is proportionately larger, may be used, having a top soldered on and an air pipe soldered on the top, which air pipe of course must be taken to the top of the cistern. It is not absolutely necessary that the muffle should be made to the exact form shown at P, Z, V, for, as before stated, a shorter one will answer, or one in the shape of a box; or instead of that, the air-pipe V, may have its end reduced to, say, $\frac{1}{8}$in. or so, and taken into a box formed in the cistern as per the dotted lines, 3, 4, or otherwise, and which I prefer to make. But notice: should the latter method be adopted, you must be careful not to have the filling hole L, into the box too large, or otherwise this filling hole will supply the air-pipe too fast, and the consequence would be that the air-pipe would become a continuous syphon. Of course, if this be closed in a box, an air-pipe must be fixed to allow it to fill or empty. The action of these muffles is as follows:—The water, on being turned on at the stopcock J, Fig. 1,085, will very quickly fill up the pipe B. It then fills the pipe V; but by reason of this pipe having its end partially closed to, say, $\frac{1}{8}$in., as at Z, the water is checked from entering the muffle rapidly, but allows it to fill very slowly. Say that it is full. Now, by drawing water through the pipe B, a portion of the water leaves the muffle, and in strict accordance with the size of the hole in the end of the pipe V; if water be continually drawn full bore through the pipe B, the muffle will empty; but if the water is not drawn full bore through the pipe B, the chances are that it will not empty; should the cock J be shut off, and the water allowed to run out of the pipe B, it will quickly empty the muffle P, and so give air into the pipe B.

I have described these muffles at length because they are not hitherto known to the public. By the use of this little invention, the gurgling noise heard when the pipes are allowed to draw air is thoroughly avoided.

Instead of using stop-cocks, as before remarked, spindle valves may be employed, as shown at D, &c., Fig. 1,086; but if these valves are used, use a valve at least one size *lead pipe* larger than the pipes employed—viz., if a $1\frac{1}{2}$in. pipe is used, use a 2in. spindle valve, and if a $\frac{3}{4}$in. is used, use a 1in. spindle valve, and so on accordingly. Fix an air pipe, as shown, to the valve; but if this air pipe has to be branched into the lead pipe below the cistern, then use a larger size lead pipe from the spindle valve to the other side of the branch on the air pipe; use, say, two or three sizes larger spindle valve and out-go pipe; this will allow the water to freely supply the mouth of the down pipe without drawing air. This is rather important. A good check against this kind of thing is to use as large an air pipe as possible, and to hammer up the branch in end of the air pipe to about $\frac{1}{8}$in. bore as at G, Fig. 577; then the air pipe will fill slowly and hold the water a good length of time whilst the draw-off pipe is at work, and so prevent the entrance of the air when a larger quantity of water will pass down the pipe in a given time than otherwise can possibly take place.

Overflowing Wells.

We will finish our Well and Water Supply Work with an illustration of an overflowing well at Bourn, in Lincolnshire (Fig. 1,086A), which is a true representation of the work of Messrs. Isler and Co., completed at the latter end of 1893. The well was sunk and bored to a depth of 134ft. for the supply of water to the town of Spalding, Lincolnshire, the yield being 5,000,000 gallons per day. Here, you see, a pipe is brought to the surface of the well, upon which is a shut-down valve.

Owing to the high pressure which there exists, great care was necessary, when putting down the tube, that there should be no chance of escape of the water outside the tube to cause unnecessary waste.

In this well there are three tiers of pipes brought within 6ft. of the surface, the ends of each being driven tightly into the soil, clay, &c., the annular space being filled in with specially prepared cement, in order that there should not be the least chance for the water to escape between the earthwork and inner tube. The outer tube is 22in. diameter, 10ft. long; the middle one, 18in. diameter and

FIG. 1,086A.

32ft. long; the inner and main tube is 13in. diameter and 76ft. long.

The well being sunk to a depth of 6ft. and 6ft. in diameter through the Fen beds, and properly steined in brickwork and cement, clay was found at 6ft. 6in. At 7ft. 6in., a loamy clay was found; at 9ft. 6in., rock and shells; at 16ft., 6ft. 6in. of limestone ("Cornbrash"), at which depth terminated the outer tube. At 30ft., was 10ft. of mottled clay, dark and green; then 1ft. of shaly clay; at 33ft., was 2ft. of hard blue rock. Here terminated the middle tube, and the cement was poured into the aperture between the 22in. and the 18in. pipe to ensure the non-escape of the water.

At 34ft., was 1ft. of dark blue soft rock and shells; at 36ft., was found 2ft. of hard blue clay; at 43ft., was found 7ft. of limestone. Here was discovered the great oolite series. At 47ft., was 4ft. of limestone of light colour; at 48ft., was found 1ft. of very hard green rock; at 55ft., was 7ft. of dark green clay; at 56ft., was 1ft. of hard blue rock; at 65ft., was 9ft. of dark and light green clay; at 65ft. 10in., was 10in. of rock with water; at 75ft. 6in., was 9ft. 8in. of light green and sandy clay; at 76ft., 6in. of black clay and peat. Here ended the 13in. inner tube, which is 76ft. in length. At 76ft. 6in., was 1ft. 6in. of grey porous rock (Lincolnshire oolite); at 134ft., was 22ft. 6in. of hard oolite limestone without tubing.

At the depth of 65ft. from the surface was found chalybeate water, which was carefully eliminated by the driving of the 13in. pipe.

At a depth of 78ft. 6in. from the surface, the main springs were tapped in the Lincolnshire oolite, the water rising very slowly, and took something like twenty-four hours to fill the well; but by continuing the boring to 100ft., the supply was 1,300 gallons per minute overflow.

At 120ft. from the surface, the spring gave 1,800 gallons per minute, and was nearly doubled when the boring was finished—134ft.

It is curious that the pressure remained the same at each of the above given depths of the boring, which is only 10 lbs. to the square inch.

The water flows by gravitation through ten miles of piping to the company's reservoirs at Spalding.

GEOMETRY FOR PLUMBERS.

Introduction.

Geometry appears to have been known hundreds of years prior to the Christian era, for the founder of scientific geometry appears to have been Pythagoras, B.C. 568. Plato was also a geometrician. The next name worth mention is Euclid, whose books are well known, and used by men of science of the present day, although more than 2,000 years old. Archimedes, another old geometrician, who lived 2,190 years ago, partially owes his success to his knowledge in this science. He was a great scholar and mechanic, and it is said that he was the first who attempted to solve the relation of a straight line to the circumference of a circle. Doubtless in my mind geometry was known to the ancient Egyptians.

If these mechanics of old knew the value of geometry in their work, surely the artisans of our age should appreciate such knowledge, and every facility should be placed in their way to acquire it, more especially as time now is one of the principal features in the master's estimate for a building. Every mechanic employed in a building should be compelled to pass an examination in the elements of geometry before he could be called an artisan, because thereby he would be more valuable to himself, and, of course, much more valuable to his employer. What does this knowledge do for the workman? It teaches him the direct road to mark out any object, and demonstrates to him the properties of magnitude—such as solids, surfaces, lines, or angles, so much needed in our trade. Now, as a practical man, having had quite forty years' experience in the working part of the building trade, I say that my labours, through my knowledge of geometry, shorthand, and mechanics, have been reduced to quite half of the general run of my fellow workmen who do not know these sciences, for, instead of being harassed when the cramp-work had to be done, it has not only been a pleasure to me, but also has been a considerable source of profit to the employer or myself; and hence the reason why I have always happily held a good position in our trade. Geometry is divided into two parts—theoretical and practical: the former teaching the properties of extension abstractly, the latter applying the theoretical properties to the purposes of life, &c.

Plane geometry treats of length and breadth. Solid geometry treats of the length, breadth, and thickness.

Explanation of terms:—

Magnitude is that which is extended, and therefore may be conceived to be contained, or limited by some certain term, or terms.

A mathematical point has neither length, breadth, nor thickness; in fact, it is an imaginary point. That which we make with the point of our pencil is not in reality a mathematical point.

A line is length without breadth or thickness, called a right line, and is the nearest route between two points, as at A, B, Fig. 1,086*.

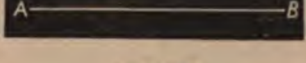


FIG. 1,086*.

Parallel lines are lines running side by side of each other, having the extreme points exactly the same distance apart, as at A, B, C, D, Fig. 1,087.

FIG. 1,087.

You now know what a point and line is, and know that two lines having their distant points equal are parallel; therefore the ends of parallels may be extended for ever in space without meeting. Angles:—If two right lines be inclined to each other so as to meet, they will form an angle; therefore an angle is the inclination or opening of two lines meeting in one point, as at B, A, C, Fig. 1,088.

FIG. 1,088.

A is the angular point. Angles are known as acute or obtuse, when as at Fig. 1,088, it is an acute angle. Right angles are those having two right lines standing perpendicular to each other, as at Fig. 1,089; this is an angle of 90 degrees. Do not confound the term perpendicular with that of vertical. The latter signifies that the line shall

FIG. 1,089.

be plumb, or at right angles to the horizon; but a perpendicular line signifies the line to be square with another as square to the pitch line of a roof, whilst the vertical line is plumb, or upright to the same, as walls to the ground. A

FIG. 1,090.

weight falling of its own gravity through space must fall in a vertical line to the horizon. The obtuse angle is any angle wider than a right angle, as at B, A, D, Fig. 1,090.

Triangles differ in shape according to the length of their sides or angles. An equilateral triangle has all its sides equal, as at A, B, C, Fig. 1,091.

FIG. 1,091.

An isosceles triangle has two sides equal, as at A, B, C, Fig. 1,092, and A, B, C, Fig. 1,093.

FIG. 1,092.

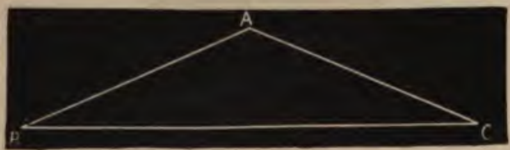


FIG. 1,093.

A scalene triangle has the three sides unequal, as at A, B, C, Fig. 1,094.

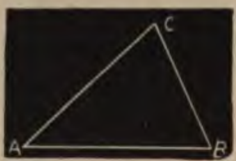


FIG. 1,094.

A right-angled triangle is one which contains a right angle — that is, an angle of 90 degrees, as at A, B, C, Fig. 1,095.

A triangle cannot have more than one right angle. The side D, or C, B, Fig. 1,095, is called the hypothenuse, and is always the longest, being opposite to the greatest angle.

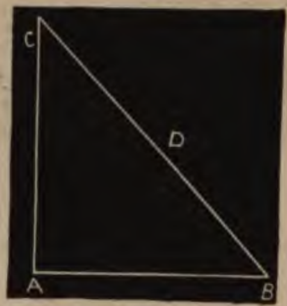


FIG. 1,095.

An acute-angled triangle has all its angles acute, or less than right angles, as at Figs. 1,091, 1,092, and 1,094.

An obtuse-angled triangle has one obtuse angle—that is, greater than a right angle, as at A, Fig. 1,093.

An isosceles triangle and a scalene triangle may be right, obtuse, or acute-angled.

All four-sided figures are called quadrilaterals, variously named according as their sides are equal or unequal, and their angles right or otherwise. A quadrilateral having its opposite sides parallel is called a parallelogram. When the angles of a parallelogram are all right angles, it is called a rectangular parallelogram, or a rectangle, as a brick; it is also called an oblong, see A, B, C, D, Fig. 1,096. A square

FIG. 1,096.

FIG. 1,097.

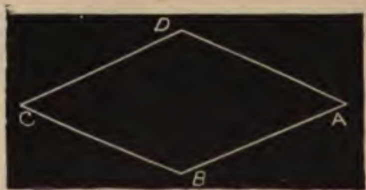


FIG. 1,098.

is a figure of four equal sides, containing equal angles, as Fig. 1,097. When a parallelogram is not rectangular, it is called a rhombus, as Fig. 1,098.

When two sides of a quadrilateral are parallel, it is called a trapezoid, as Fig. 1,099.

Fig. 1,099.

A trapezoid has only one pair of sides parallel, as Fig. 1,100, but may have one end square, as at A, C; this is the shape of a close boiler for kitchen ranges.

Fig. 1,100.

When a quadrilateral, or four-sided figure, has none of its sides parallel, it is called a trapezium, as Fig. 1,101.

Fig. 1,101.

A cube is understood to be a regular solid six-sided figure, having all its sides of equal length, and containing equal angles.

Multilateral figures, or polygons, are those having more than four sides—such as the pentagon, or five-sided figure; the hexagon, or six-sided; the heptagon, or seven-sided; the octagon, or eight-sided; the nonagon, or nine-sided; the decagon, or ten-sided; the undecagon, or eleven-sided; the dudecagon, or twelve-sided. If all the sides are equal, then the angles will also be equal, and the figure will be a regular polygon; if unequal, it is called an irregular polygon.

The base of a figure is the bottom side or line upon which it is supposed to stand, as at A, B, Fig. 1,091.

Altitude is the perpendicular height from the base to the highest point, as at C, Fig. 1,091.

The area of a plane figure is the quantity of space impounded in or between the lines A, B, C, Fig. 1,091.

Fig. 1,102.

A circle is a plane figure bounded by a curved line called the circumference, returning from whence it started, as Fig. 1,102. The circumference is known as the boundary line.

The radius of a circle is a straight line drawn from the centre to the circumference, as at A, B, Fig. 1,102.

The diameter of a circle is a line drawn through the centre, and continued to the circumference each side; therefore every diameter shall divide the circle into two equal parts.

A segment of a circle is that part of its circumference cut across with a line, as at D, E, Fig. 1,102; but not through the centre. This line is called the chord of the segment or arc.

A tangent is a straight line drawn so as to touch the circumference of the circle without cutting it, and is shown at E, D, Fig. 1,103; the point of contact is that at E.

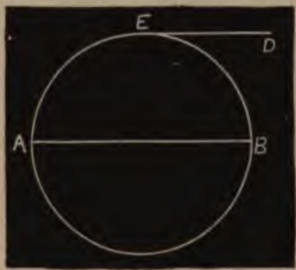


Fig. 1,103.

A secant is a line drawn from the centre through the extremity of an arc to meet the tangent drawn from the other extremity, as at A, B, Fig. 1,104.

Fig. 1,104.

A sector of a circle is a space comprehended between two radii and an arc, as the envelope of a cone, as at A, B, C, Fig. 1,105.

Fig. 1,105.

Circles are divided into 360 parts, called degrees; a these degrees into 60 parts, called minutes; and the minu into 60 parts, called seconds—the angles are known these degrees. When we speak of an angle of 90 degree we mean that it is the quarter of a circle.

In order to measure the angle a circle is described round the angular point, as at B, C, Fig. 1,106, and according to the number of degrees cut off by B, A, C, A, so many degrees will be contained by the angle. Mark degrees thus °, minutes thus ′, seconds thus ″. The degrees contained by any angle are measured with the little half circular instrument called a protractor, and is used as follows:—Place the centre or base line of the instrument on

FIG. 1,106.

the line B, A, Fig. 1,105, and if properly read off C, A, will be 46°. We unite degrees, &c., thus 46°, 3′, 1″, means 46 degrees, 3 minutes, 1 second. If you again refer to Fig. 1,106 you will there see the circle divided off into four equal parts, as at A, B, C, D—then if B to D is a quarter of the circle, and if there be 360° in a circle, it follows, and is plainly seen, that from B to D must be an angle of 90°. Next divide the circle into eight parts, as at B, C, F,

FIG. 1,107.

Fig. 1,107. Here D, C, F, is an angle of 45°. I particularly wish you to become well grounded in these angles, because a thorough knowledge of them will constitute the most important part of your work, and will greatly facilitate it.

Concentric circles, A, B, Fig. 1,109, form an important part of plumbing work, as all pipes may be considered to be concentric circles. The space included between the circumferences is called a ring; this also represents the end section of a pipe. For the area, see Problem 25.

Other terms will be explained as we go through the work. I shall also point out the problems most suited for plumbers' work.

The tools required for this work will be as follows, and may be procured at any stationer's (or they will get them for you), or you may procure them often at pawnbrokers' shops, oil and colour shops, &c. Mr. Stanley and Mr. Archbutt are very good makers. First, a pine drawing board, which any carpenter will make for you for about 1s. 6d. or 2s., should be, for this class of work, about 18in. by 21in.; some drawing pins for fixing your paper to the board; next, some paper, good lining paper will do for this work, or you can buy some sheets at a stationer's shop; next, a pair of compasses, a pencil, and a ruler—work with

FIG. 1,109.

these until you have thoroughly mastered the principles hereafter to be laid down. After this you will require a set of instruments, such as a pair of dividers, a pair of compasses having ink pen, a drawing pen, rubber, T square, a set of set squares, and a builder's or engineer's scale (the scale will cost you 1s. 6d.). If you wish for a good set of instruments you may obtain them for about 40s., and the set of squares for about 4s.

Problem 1.—Draw three arcs, which shall be in a true line and parallel to a given base line, as Fig. 1,110.

Draw the line A, B, and mark the points of same; next open the compasses to the length of the line A, B, so that it will mark each point, then fix one leg on the point A and strike the arc D (this will be the longest line, and also the arc C, also the longest line or semi-circle), then from the other end of the line B strike another line or arc intersecting at the point D, also strike the arc E; next place the leg of your compasses on the intersected point at D, and strike the line or arc F and also G, when these three points will be in

FIG. 1,110.

a straight and parallel line with A, B. This is handy when you want to cut out lead parallel to the sides or edge line. Or otherwise, suppose A, B to be the end of the sheet or other piece of lead which has not been cut off square, you require to cut a piece off to the exact same angle and parallel to A, B, and have no templet or other means of doing it but by the compasses and chalk line. This problem, if expeditiously done, will come in handy when cutting out lead or setting out work on the floor.

Problem 2.—To divide a given line into two equal parts. From the points A, B, Fig. 1,111, as centres, strike the arcs C, D, and draw a line cutting these arcs; this line must be central, and A, B is equally divided. This is very handy, both on the bench and on the building—in fact, I think it

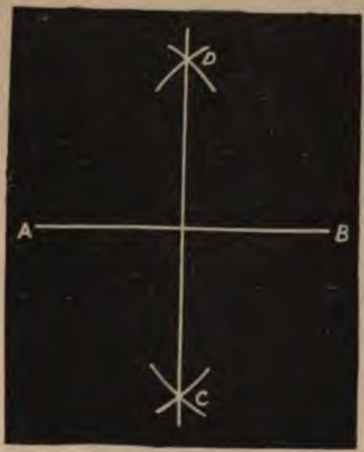


FIG. 1,111.

is one of the most useful problems in geometry; here you divide your piece of lead, get a square, divide a circle, and many other things at one and the same time.

Problem 3.—From a given point on a line to raise a perpendicular line.

Draw the line A, B, Fig. 1,112, place the point of the compasses in any part of the line, as at D, and strike the arcs F, G; next from these arcs as centres strike the arc E as shown, draw the line from E to the given point D; here you obtain a square which is always handy in setting or cutting out. But suppose you want the perpendicular line at the end of a given line or point (such as, say, the end of a measurement for cisterns, bays, &c.), then draw the

FIG. 1,112.

straight line A, B, Fig. 1,113, which now represents the side of a sheet of lead, or stone, or piece of board, put in the point B as a centre, strike the semi-circle or arc C, E, D, place the leg of the compasses upon the point C and strike the arc E, cutting the arc C, D at E; next place the leg of the compasses on the intersecting points of the arcs at E and strike the arc D; next from these points D, E, strike the arcs F, and from this point draw a line cutting the measured point B—this will be dead true. Another method: Let A, B, Fig. 1,114, be the given line, and B the point for square line to cut. Take the compasses and place the leg on the point B, the other leg anywhere about E, of course within the required square line, strike the circle cutting the line A, B at C; next draw a line through the intersecting

FIG. 1,113.

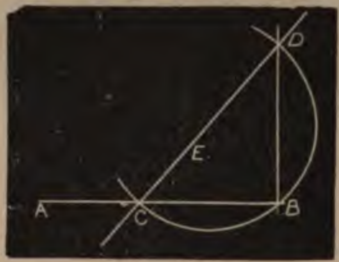


FIG. 1,114.

point C and the centre point or compasses point E. This line will, if extended to the circle, give another intersecting point D, and from this point to the measured point B will be perpendicular or square to the line A, B, therefore draw the line from B to D for cutting. Another method also,

FIG. 1,115.

when using rods in lieu of compasses for large work on t floor, ground work, &c. Let the line A, B, Fig. 1,115, l say, 16ft. long, measure off from the measured point three yards and mark it, as at C, or 3ft. will do; then fr... B along the line A, B measure four yards as at D, fix the

rod at B, which will be four units or yards long, and work the end round about the part E, so as to mark a part of a circle or arc as shown. Next measure off along the line, as at A, five yards or units, and with this distance from the measured C point of three yards fix the rod five yards long and mark the arc L, K, cutting the arc E; this will be square with B, A. This may be struck with the chalk line instead of rods, and is called getting a square with a line. Another method is illustrated at Fig. 1,116. Draw the line A, B, and from the point B, with any radius, strike the

FIG. 1,116.

arc C, D, E, and with the same radius set off from point C to the point D, and from the point D strike the arc F, and draw the line C, D, F through the points C, D, extend this line to cut the arc F, and at this point draw the line from F to the point B, which must be square.

Problem 4.—Let fall a perpendicular from a given point to a given line.

This is done as follows:—Draw the line A, B, Fig. 1,117, and put in the given or intended point C. Open the com-

FIG. 1,117.

passes, and from the given point C strike the arc cutting the line A, B, from these points strike the arc D, and draw the line cutting C and D. Another way, when the point is nearly over the end of the line, and when the line cannot be lengthened. Let A, B, Fig. 1,118, be the given line, C the given point; draw a line C, B obliquely to A, B. Bisect this line, then with the radius C, D or D, B, strike an arc cutting the given line as at E, then the line drawn through the point C, and the intersecting point of arc E, which must be square with A, B. This problem is very handy for cutting out lead from sheet; the arc H is not required at present.

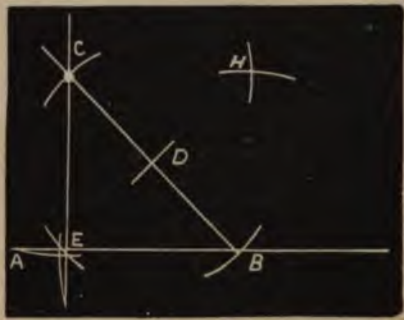


FIG. 1,118.

Problem 5.—Fig. 1,119. To bisect an angle.

Let A, B, C be the rectilineal angle to be bisected. From A, as a centre, strike the arc cutting the lines C, B,

FIG. 1,119.

from these points C, B, as centres, describe the two arcs cutting each other as at D; join A, D, which will bisect the angle as required.

Problem 6.—Fig. 1,120. Draw an angle, which shall be exactly the same as a given angle.

Here A, B, C is the given angle. From the centre A, with any radius, strike the arc B, C, then draw the line D, E, and with the same radius, and from the point D, strike the arc

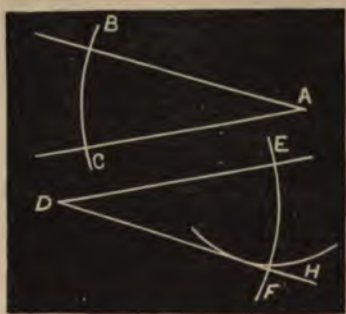


FIG. 1,120.

E, F; then place the leg of the compasses on the point C and measure the distance to B, with this distance measure from E to F, striking the arc H; next draw the line D, F through the intersecting points of the arcs, and the two angles shall be the same. This is one of the most simple

yet most instructive and important problems in geometry for *plumbers*; it is the best way of taking the angles for dormers or bay windows, gutters, &c.

Problem 7.—Fig. 1,121. To trisect a right angle.

Let A, B, C, Fig. 1,121, be the angle to be trisected. From the point A, with any distance, strike the arc C, D, cutting the lines A, C and A, B from D, C as centres, and with the

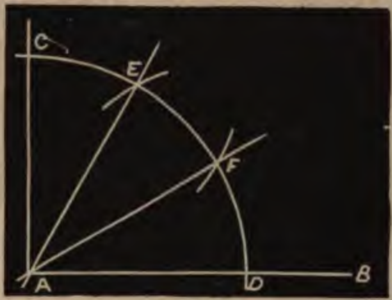


Fig. 1,121.

radius of A, D strike the arcs E, F, cutting the arc C, D. Draw the line through these arcs to the point A, when the angle will be trisected. If you wish further to divide these angles, you may do so by bisecting, as at Fig. 1,119.

Problem 8.—Fig. 1,122. To describe a triangle, three sides of which are given.

Let A, B, C be the given triangle, and D, E, F, G the length of the three sides. First draw the line A, B equal to F, G, then take the compasses, and with the line F, G as a radius from the point A, strike the arc C; next take the line

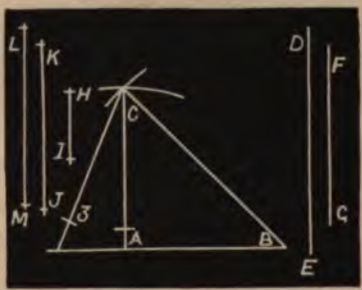


Fig. 1,122.

D, E for the radius, and from the point B strike the arc cutting the arc C, then draw the lines A, C and C, B, and you have the required triangle. Work the lines H, I, J, K, L, M, into a triangle, and prove whether they will form the triangle.

Problem 9.—Construct an equilateral triangle, as at Fig. 1,091.

Draw the line A, B, and with this line, as a radius from the points A, B, strike the arc at C, also the other arc, with same radius, cutting the arc C; draw the lines A, C and C, B, which must form an equilateral triangle. Test the equality of the angles, as at Fig. 1,120.

Again, set up a right-angled triangle, as at Fig. 1,095. Also set up an isosceles triangle, as at Figs. 1,092 and 1,093. Set up a scalene triangle, as at Fig. 1,094.

On a straight line set up the two sides of a cistern equal in height to the straight line, which shall be perpendicular. What will be the position of these sides to each other? Will they be parallel and form an angle with each other; if so, what angle? At the top of one of these lines set off another line which shall be square to the said erected perpendicular lines; this done, what will be the relationship of all the angles to each other? *Right angles.* Draw a diagonal line from corner to corner; what will be the triangles? *Right-angled triangles.*

Problem 10.—Fig. 1,123. Construct a double equilateral triangle below and on a given straight line, with only two moves of the compasses.

Fig. 1,123.

Draw four lines through these triangular points, and all four will be parellel lines; this marks out a true quarry for lead light glazing. See Lead Light Glazing, Vol. I.

Area of Triangle.

To find the area of a triangle; multiply the base by the perpendicular height, and divide the product by two for the area.

Problem 11.—Fig. 1,124. Draw a line parallel to a given line A, B.

Fig. 1,124.

Open the compasses and strike two arcs as at C, D, draw a line cutting these arcs, and it will be parallel to A, B. Another method is to erect perpendiculars on the given line, and from their points at the base strike arcs as before.

Problem 12.—Fig. 1,125. To draw a line paralle[l] another from a given point in the same.

Open the compasses with a longer radius, then from point to the given line, and from this point, st the arc cutting the line at A, next from the point A, w the same radius, strike the arc E, also cutting the l Next measure from this point to the given point C,

with this radius, from the point A, strike the arc D cutting the arc A, D, and draw the line D, C, which must be parallel to A, B.

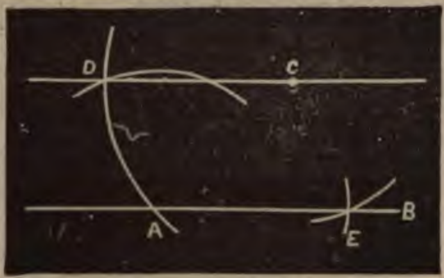


FIG. 1,125.

Problem 13.—Fig. 1,126. To construct a square upon a given straight line.

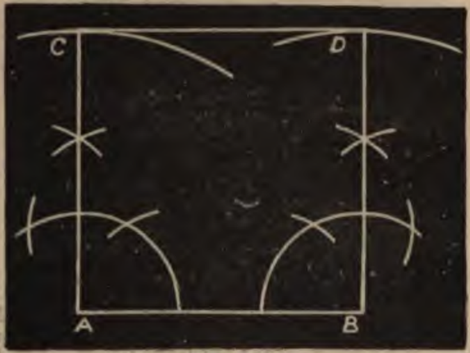


FIG. 1,126.

Let A, B, Fig. 1,126, be the given line. Erect two perpendiculars, as at Fig. 1,113, the same distance apart as length of line. With this distance strike the arcs C, D, and draw the line; this will form a square.

Another way, as at Fig. 1,127. With the compasses take the length of the line A, B, and with B as a centre, describe the arc A, E, C, then take A as a centre, and with the same radius describe the arc B, E, D, making the intersecting point E. Next, from E as a centre, and with the same

FIG. 1,127.

[illegible] strike the arcs intersecting the arcs D, E, B and [illegible] the points C, D, and draw a straight line to cut [illegible] (dotted lines); then with the radii E, G [illegible] and from B as a centre, strike the arcs L, N, [illegible] the lines, so forming a square.

Here you have an equilateral triangle; the angles A, B, E and B, E, A are each two-thirds of a right angle, these being bisected by the arcs A, C and B, D, the angles A, E, L and B, E, N are therefore equal to one-third of a right angle. The angles N, B, A and L, A, B are, of course, right angles, and therefore L, A and N, B must be equal and parallel—the result being that A, B, L, N must be a square.

Another method, Fig. 1,128. A, B is the given line. From these two points as a radius and centres describe the arcs giving the point C, from this point strike the arc H, I, J, draw a line from the point B through C cutting the arc

FIG. 1,128.

H, I, J at E, also from A, C to D. The lines A, G, E and B, F, D will be square to the given lines, and therefore parallel to each other. Draw the line L where you may require it. This is a very handy method of getting a square about a building.

If you notice this Fig. you will see the simple reason why this forms a parallelogram. The points D, E are placed in a line with the centre C, and in the semi-circle which passes through B, A, as at Fig. 1,114. As a proof of this, see Problem 14.

Problem 14.—Fig. 1,129. Draw a circle, then the chord

1,129.

A, B; next draw two diagonal lines passing through the centres of the circle as at C, continue the same to outside of circle. These points will be parallel, perpendicular, and square to the line A, B—such are the rules of geometry.

Problem 15.—Fig. 1,130. To divide a straight line A, B into any number of equal parts.

First draw the two lines D, B and A, C parallel to each other as shown, the end of each touching the points of the line A, B, then (say the line is required to be divided into five parts) take any distance, and from the point B along the

FIG. 1,130.

line B, D set off as many parts as you require the line to be divided into, then do likewise from point A along the line A, C, draw lines from these points cutting the line A, B, which must be divided accordingly. If you have a set square you can do this with one line; this is, of course, to get the parallels.

Problem 16.—Fig. 1,131. To trisect a given straight line.

Here we have a line to trisect. Of course, you know how to bisect a line, and you may ask why I did not show you how to trisect a line at the same time. The answer is, because you were not far enough advanced; for here you require to know how to construct an equilateral triangle,

FIG. 1,131.

how to draw parallel lines, &c. Now let A, B, Fig. 1,131, be the given line, construct an equilateral triangle upon it, bisect the two sides, and get the points C, D, from these points draw lines to cut the end of the given line as at A, B, and forming the point E. Next through the point E draw parallel lines to the sides of triangle A, H and B, H, draw the two lines F, E and E, G parallel to these sides, cutting the point E, and the line A, B will be trisected.

To construct a scale. As you proceed with this work you will find it necessary to use a scale—you may have felt the want of such knowledge when examining the ordinary building plans. Some are divided into tenths, others into twelfths; you may use either, but when reading a plan, notice how it is divided. If the feet are divided into inches, then, of course, the inches will be twelfths; if the feet

FIG. 1,132.

only are marked, then it is divided into tenths, as 1 0. 2 0. 3 0. 4 0., and so on, and one of these tenths divide into units, Fig. 1,132, at A. This shows how to construct a scale divided into units. The divisions from 0 to 20 may represent feet, yards, or miles.

Next look at B (here you have a scale of feet and inches). Notice the end is divided into 12, which means that it is one foot divided into 12 inches.

Now if this scale were for inches and eighths of an inch, then the end, now inches, would be divided into eight parts. The method of dividing these parts is the same as that described in Problem 15, or you may first set out the inches or units, and then with the compasses open to th
of these, and set off as from 0 to 10, 20, &c.
your scales to the standard measurements it wi
well, such as $\frac{1}{8}$in., $\frac{1}{4}$in., $\frac{1}{2}$in., $\frac{3}{4}$in., 1in., 2in.,
then have an opportunity of measuring with a

To draw a diameter of a circle (see Fig. 1,133). Open the compasses, and from a point in the circumference of the circle, as at A, describe the arcs C, D; then take another point in the circumference as at B, and strike two more arcs

FIG. 1,133.

cutting the previous arcs as at C, D; now draw the line D, E, F, which will be the diameter of the circle. If you can see the centre then the matter is simplified, as a line drawn through it to the circumference is the diameter.

Problem 18.—Fig. 1,134. To find the centre of a circle. I have shown you how to find the diameter of

FIG. 1,134.

a circle. Now, before you look at the instructions given in this problem, try to do it yourself by the aid of the last problem. Draw the chord A, B (or you can do without this line), bisect it as at C, D, draw the diameter, and bisect this diameter (see Fig. 1,133). The point of bisection will be

FIG. 1,135.

the centre of circle. This is a very useful problem to the plumber when marking traps, or pipe lines through wood work.

Another method: From any point (J, Fig. 1,135) in the circumference with a radius about half that of the circle, describe an arc, or, for your first attempt, a circle. Next, with the same radius, and from any other two points, as at A, B, describe the arcs F, G and C, D, cutting the circle, draw the lines D, E and C, E; the point of intersection must be the centre of the circle. You may do this in many other ways, but this latter method is quite as expeditious as any other. You may notice that Fig. 1,134 might have been omitted; but in order to make my work simple, clear, and as little complicated as possible, so that my brother plumbers may easily master it, I find it of the greatest importance to keep the diagrams clear, and to avoid working them out at any unnecessary length.

Problem 19.—Fig. 1,136. To strike a circle through three given points which are not in the same straight line, or through any given triangle.

To show this in the simplest form strike an equilateral triangle, as at P, J, D, Fig. 1,136. Let the points of the

FIG. 1,136.

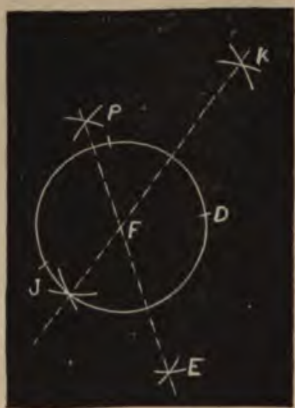


FIG. 1,137.

triangle be the given points, bisect these three lines and draw the dotted lines J, K and P, E. The point of intersection at F will be the centre point for the circle. Fig. 1,137 is the same thing without the lines P, J, D being drawn. This problem is used for cutting holes in angles, &c.

Problem 20.—Fig. 1,138. Tangents. To draw a straight line to touch a circle at a given point.

FIG. 1,138.

At right angles to the diameter A, B, Fig. 1,138, draw the tangent line C, B.

Problem 21.—Fig. 1,139. To draw tangents to a circle from a given point without it.

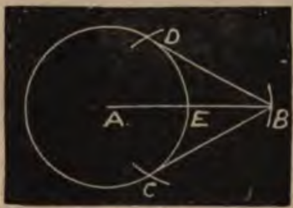


FIG. 1,139.

This requires but very little explanation From A, B, with E for a centre, strike the arcs D, C, B, with straight line from B to C, D, join the same, which must touch the circle from the outward point B.

Problem 22.—Fig. 1,140. To draw radial lines upon the circumference of a circle, or to raise perpendiculars from any point or points without finding the centre.

FIG. 1,140.

If the radii be at equal distances, set off equal parts round the circumference, as at A, B, C, D, &c., on these points as centres strike the arcs, cutting each other, as at H, I, J, &c., and draw lines B, A to H, C to I, &c. This will be found handy for circular scollop work, and many other purposes on roof work.

Problem 23.—Fig. 1,141. To draw a line equal in length to a circle or a pipe, as for soil pipes, &c. Also see Fig. 41, Vol. I., for cutting sizes of lead for soil pipes.

Describe the circle A, B, C, D, Fig. 1,141, strike the diameter A, B, and from the centre H draw a perpendicular H, B, then strike the chord line D, B, and from the ends as centres strike the arcs E and bisect D, B, also cutting the circle at G, then three times diameter of circle with the distance from the chord to the circumference of circle as at F, G, added, will be the length round pipe or circle, nearly. Or multiply the diameter by $3\frac{1}{7}$. See Problem 35, &c.

The diameter of a circle being given to find its circumference.

Remember and say as 7 : 22 :: the given diameter : circumference; or divide the diameter into 7 parts, and add

FIG. 1,141.

15 more of such parts for the circumference. Or as 113 : 355 :: the diameter : circumference—that is near enough for all practical work, and should always be in your memory. Then you may say as 22 : 7 :: the given circumference : the diameter; and so on. Explanation: is to :: so is : to. I have given these rough measurements or figures to suit the workman, knowing that they are near enough for his practical work; and to satisfy my sneering methodical reader, should there happen to be one, I would ask him, if he has nothing better to do, to see if the following is correct, and to work the problem so started. The circumference of a circle whose diameter is 1, is = 3·14159265358 97932384626433832795028841971693993751058209749445923078164062862089986280348253421170679821480865132723066470938446, &c.

To find the area of a circle. Multiply half the circumference by half the diameter for the area, or multiply the square of the diameter by ·7854 for the area.

Another method: Let half the diameter of the circle expressed in inches be found and its square taken. Let this square be multiplied by the number 3·1415, and the product will be the number of square inches in the circle. For those not well up in decimals the following simple rule may be found useful. Let the diameter of the circle be squared, and its square divided by 14, the quotient multiplied by 11 will give the area nearly, or multiply the square of the circumference by ·07958. And again, as 14 is to 11, so is the square of the diameter to the area (see Problem 36) or as 88 is to 7, so is the square of the circumference to the area.

Squaring of pipes or circles, so as to get the side of a square which is equal to the round pipe, multiply the diameter of the pipe by ·8862269, and the product will be the side of a square equal in area to the circle.

Given the circumference of a pipe or circle, to find the side of a square equal in area to the pipe or circle, multiply the circumference by ·2820948, and the product will be the side of the square.

Problem 24.—Fig. 1,142. To find the radius of a cu[rve] such as bow windows, coppers, and other curves.

Let A, B, Fig. 1,142, be the curve. From D as a ce[ntre] strike the circle E, H, G, F, and with the same radius, f[rom] about A, B, strike the arcs E, H and F, G, draw lines fro[m] where the arcs cut until the points meet as at C; this is

the centre of the curve or circle. Also see Fig. 1,135, which answers this purpose.

Problem 25.—To find the area of concentric circles, as at Fig. 1,109, or the space between two rings called concentric circles.

Multiply the sum of the two diameters by their difference, and this product by ·7854 for the area of the ring, as follows:—Take the larger diameter E, F, and call it 15, and the smaller H, I 10, and work out the following, which will be the content of the area between the two rings or circles—

```
 15
 10
 ———
 150
 ·7854
 ————
  600
  750
 1200
 1050
 ————
117·8100
```

area of space between circles. This rule will give you the area of the end of a lead pipe, from which you may ascertain the weight; it will also give you the weight of washers, &c.

Problem 26.—Fig. 1,143. To describe an arc through three given points, not using or knowing the centre of the circle

Let A, B, C, Fig. 1,143, be the points. From the point A, with the radius A, C, strike the arc C, E, then with the same radius and from the point C strike the arc A, F. Next draw the cross-line A, G from the point A and through the point B, cutting the arc at G; also draw the line C, H through the point B to cut the arc A, F. Next cut off any distance (say half of line G, C), and from the point G to I, L, also from H to J and K, draw a line from K to C, from J to C, from A to I, and A to L. Where these lines, A, I, C, K, intersect, as at P and O, will be the point to draw the curve through for the arc required, as shown in Fig. 1,143. This problem will be found exceedingly useful for cutting out lead for dome bases, circular bay windows, tops of coppers, &c.

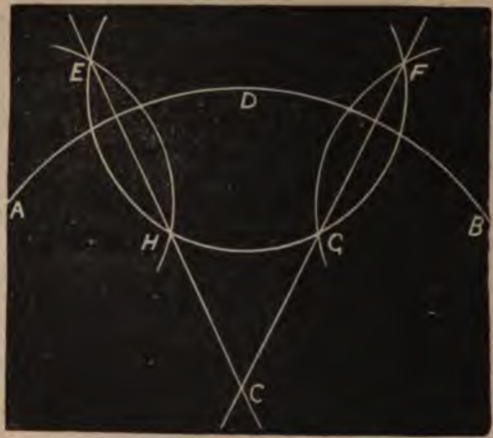


Fig. 1,142.

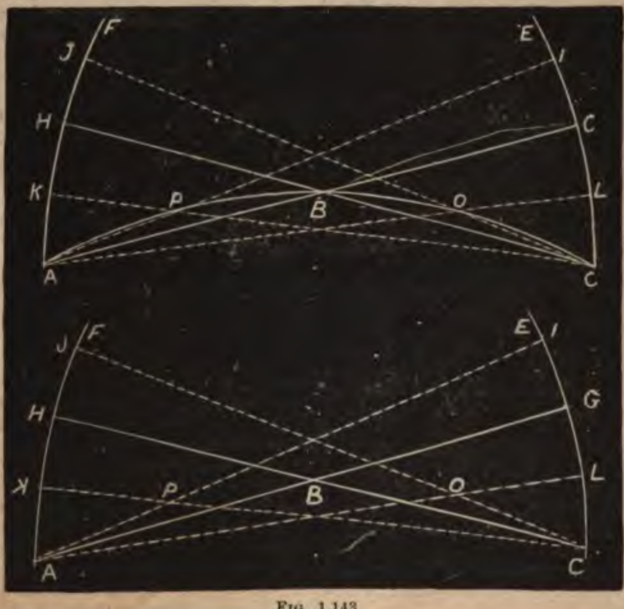


Fig 1,143.

Problem 27.—Fig. 1,144. The chord and height of a segment being given, to find the curve without having any recourse to the centre.

Let A, B be the chord and C, D the rise or height. Draw a line through point C parallel to A, B, and divide A, B at D; next draw a line from A to C, set off from point A the line A, K perpendicular to A, C, also B, J perpendicular to B, C; now divide the lines K to C, and C to M and A, D, and B to D, into an [illegible] of parts; also draw the lines A, N and B, M [illegible] A, B, and from these points divide these [illegible] number of parts, as

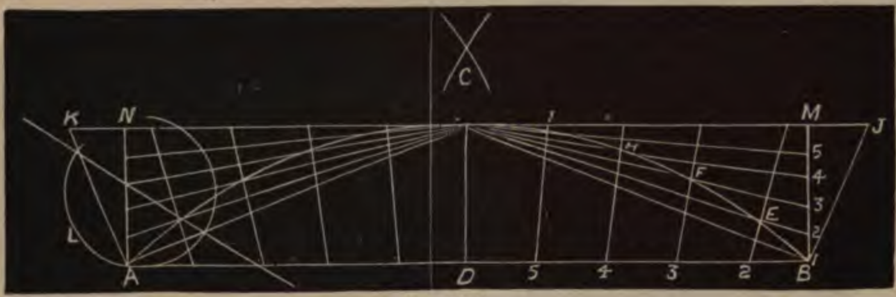


FIG. 1,144.

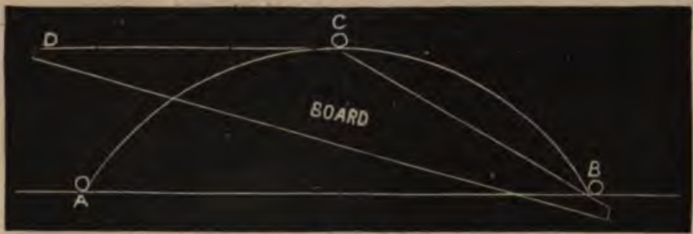


FIG. 1,145.

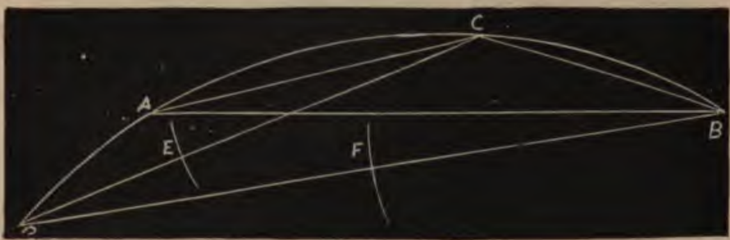


FIG. 1,146.

from D to B (namely, five), draw lines from C to the points 1, 2, 3, 4, 5, line B, M and A, N, and also the line on A, B and K, C, C, M and D, B. The points of intersection will be the points for the curve line, as at E, F, H, I.

Segmental striking with a triangle or triangular guide.

Fig. 1,145 shows an easy method of striking segments with a triangular straight edge. Let A, B be the segment and C the required height; now place three bradawls at these points and draw the line A, B, place a piece of board (cut as shown) from C to B on the taper, and next cut C, D parallel to the line A, B, then by moving the triangle against the bradawls from left to right the point C will describe the required segment.

Problem 28.—Fig. 1,146. To continue to any extent an arc already laid down.

Let A, B, C, Fig. 1,146, be the arc to be continued. Draw lines from A, B and A, C and C, B, next draw at any angle the line D, C, set off the distance C, E and place this in the line from B to F, measure the angle D, A, C as at E, and with this distance set off at F for the angle D, A, B, draw the line D, B, cutting the line D, C at the point D; this will be the point for the continuing of the curve or arc. Should you wish to continue the curve, you can do so by setting off other pairs of equal angles from A, C and B, C.

Problem 29.—Spirals or curves. Fig. 1,147, invented by Archimedes.

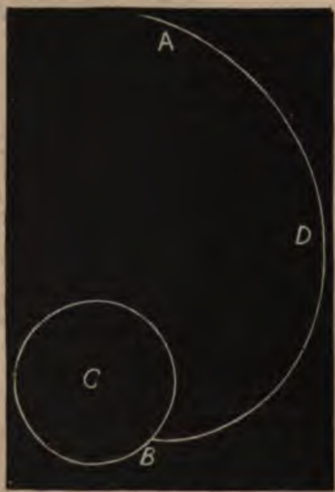


FIG. 1,147.

A spiral or curve is a figure in which no part, however small, is straight, neither should there be any part of a circle within the bounds of a curve. The curves generally referred to are the ellipsis, the parabola, the hyperbola, and the cycloid. The curve may be struck in many ways, but the simplest is that described at *Fig.* 1,147. Let C be a small curve or a circle—a piece of cork will answer very well; wind a piece of thread round this cork with a loop on the other end to put a pencil through, then if the point be placed upon the paper, and you unwind this thread, keeping it tight upon the curve or convexity of the circle, its end A will describe the true curve B, A. The primary curve or circle, or that which the thread is wound upon, is called the evolute, and the curve A, B formed by the unwinding of the thread is termed the involute. Of course, the thread at every point during the unwinding is a tangent to the evolute.

To describe a so-called spiral with compasses. Draw the line A, B, Fig. 1,148, and from the centre of this line set off as many equal parts as you may require, as at I, H, F, E, J, K, L, M; from two of these points, about the centre of the line, strike the half-circle as from E to J, M to N, &c., or, in other words, strike a half-circle in a line, and from the point where the arc terminates place the leg of the compasses; here open them to the diameter of this half-circle, and from the other part of the circle strike again to cut the straight line. If you divide this spiral into equal parts it makes a first-rate domical strainer pattern, as shown by the small circles; to get the size of lead, see Figs. 1,154 and 1,155. Before we can proceed much further, we must know something more about dividing and proportions. Also see Fig. 1,189.

FIG. 1 148.

Problem 30.—Fig. 1,149. Divide proportionally a given line similar to one divided.

Let A, B, Fig. 1,149, be the line to be divided, and C, D the divided line, which is longer; join the line A, D, then draw the line A, C, and from the divided points E, F, G draw lines parallel to A, C, cutting the line A, D; next draw the line B, D, and from the points of the lines J, I, H draw lines parallel to B, D, cutting the line A, B, and the

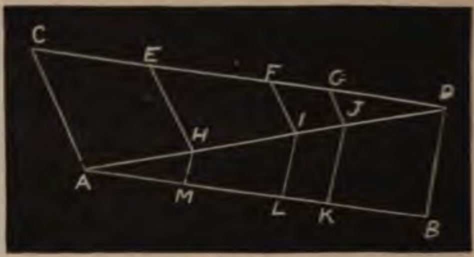


FIG. 1,149.

line A, B will be divided similarly and in proportion and equal to C, D.

Problem 31.—Fig. 1,150. To find a third proportional to two given lines.

FIG. 1,150

Let B, D be one of the lines 9in. long, and let B, C be 8in. long ... C, D from the point C in the line C, D,

draw the line A, C at right angles, cutting the line A, B, when A, B will be the third proportional; D, B is 9in., B, C 8in., A, B 7in. Or let A, B and B, C be the given lines, in this case B, C is longer than A, B, and therefore B, D will be longer than either of the given lines; they will be 7in., 8in., and 9in. respectively—so that you may work this problem either way.

Problem 32.—Fig. 1,151. To find a fourth proportional to three given right lines, as at A, B, C, D, E, F.

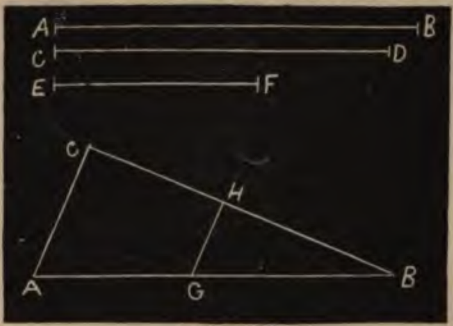


FIG. 1,151.

Let A, B and C, D form an angle, as at A, B, C, on the line A, B, and from the point B set off the point G equal to E, F; next join A, C and draw G, H parallel to it, then B, H will be the fourth proportional.

Problem 33.—Fig. 1,152. To find a mean proportional to two given straight lines.

Draw the line A, B, Fig. 1,152. Let A, C be 9in. long and C, B 6in. long, bisect A, B and strike the arc cutting the ends of the line A, B, erect a perpendicular at the ends of the longest line, namely, at C—let this perpendicular cut

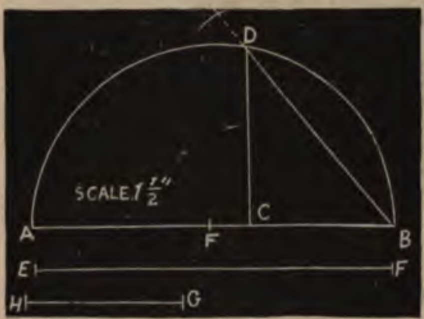


FIG. 1,152.

the arc as at D; the line thus formed must be the mean proportional line between the two given straight lines. Or let E, F be the longest line, as at A, B, describe the semi-circle, then take H, G, place it at C, B, and erect a perpendicular C, D as shown, cutting the arc; then draw the line D, B, which must also be the mean proportional.

Problem 34.—Fig. 1,153. Divide the circumference of a circle into any number of equal parts, or inscribe any regular polygon in a given circle, in this case a pentagon (also see Problem 40).

Strike a circle, Fig. 1,153, draw a diameter, bisect this diameter in C, and erect a perpendicular, carrying the same anywhere beyond the radius of the circle. Divide the diameter into as many parts as there are to be sides in the polygon (in this case five), next divide the radius C, D into four equal parts as at E, F, G, and set off three of these parts from D to H; next draw a line from the point H through the second division on the diameter as shown at 2, let this line be continued to the circle as at J, and join A, J; this will be the length and side of the required polygon. Very handy for shop work.

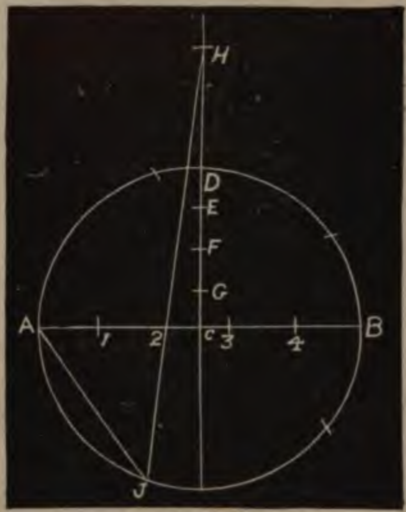


FIG. 1,153.

Problem 35.—Fig. 1,154. To draw a right line equal in length to a given arc, or part of a circle, suitable for flushings, round coppers, &c., also for lining half-circles.

FIG. 1,154.

Draw and divide the chord A, B into four equal parts, and set off one of these parts round the arc as at C, then join C and the divisional point D on chord, then C, D will be in length half the circumference of the arc, *or nearly*. *Handy for roof or shop work.*

Another way. To draw the exact size of a piece of lead for a domical strainer, half-ball, &c.

Let A, B, C, Fig. 1,155, be the half-ball to be covered, and A, B the diameter of a circle (*which the arc I, J, if continued, would form*), take the compasses set to this diameter, and from A to B, D strike the arc B, D, then from B as a centre, with the same radius, strike the arc A, D. The point D will be the principal point to work from, as follows:—Suppose you want to cover half a ball, as at A, C, B, then from the point D draw a line from the point B as at D, B, H; next draw the line from the point D through the point A, forming the line G, A, D; next draw the line G, H parallel to the line A, B, and the lines G, D and H, D, at G and H—the line G, H will be the circumference, length, or strike outline for covering the half-ball, and the dotted circle A, G, L, M, B will be the size of the disc struck from the centre C. Should you only require to cover part of the ball, as from I, J, work as before, but draw the lines F, D and E, D through the points of the arc and chord, as at I, J; then draw the line F, E parallel to the chord line I, J, which will give you

First draw a circle, having the required diameter, namely, the length of the given line A B, then with the same radius divide the circumference of the circle into six equal parts—they will be the points of the hexagon. Notice the points A D E. Here you have an equilateral triangle, but the hexagon is formed with six equilateral triangles. To prove this, draw lines from corner to corner, as at Fig. 1,163, all meeting in the centre. If you study this figure carefully you will see that this is one of the three

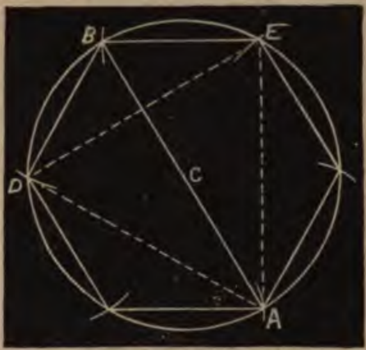


FIG. 1,159.

geometrical diagrams (namely, the equilateral triangle, the square, and the hexagon) which can be fitted together so as to cover a flat surface, without any interstices between the corners or pieces used, so that it may be used on floors, on pattern lead, or pewter, zinc, copper, brass, bronze, &c.

Problem 39.—Fig. 1,160. To draw a hexagon upon a given line.

FIG. 1,160.

Let A B be the given line. From the points A B, and with the distance A B, draw the arcs C, which will give you the centre for striking the circle. This circle will require to be divided to form the hexagon as in the last problem.

Problem 40.—Fig. 1,162. To make a regular polygon of any number of sides within a given circle. In this case a hexagon, see Problem 34.

Having the circle, draw the radius A B, Fig. 1,162, next divide the number of degrees in the circle, which is 360° by 6, the number of sides here required (if eight sides were required you would divide by eight, and so on). In this case you find the division by 6 to produce 60°, which is the number of degrees in the angle A B C, then a chord from A C will be the side of the polygon. This is very handy when drawing, as it can be done instantly with the protractor and a few figures.

Heptagon, or seven-sided figure. Construct as per Problems 34 and 40.

FIG. 1,162.

Problem 41.—Fig. 1,163. To describe a regular octagon in a given square.

Let A B C D, Fig. 1,163, be the given square. Draw the diagonal lines B C and A D, intersecting at E; upon the

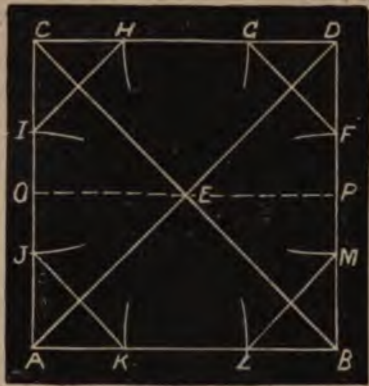


FIG. 1,163.

four corners A B C D, as centres, with A E as radius, draw the arcs F G H I J K L M, cutting the line A B C D. Draw lines as from F G, H I, J K, L M—these give the required octagon.

Problem 42.—To draw a duodecagon.

Draw the two diameters A B and C D, Fig. 1,164, at right

FIG. 1,164.

angles to each other, draw the arcs E F and G H, &
will give you twelve sides.

It is unnecessary further to describe polygons by diagrams, but for reference the subjoined table of polygons, together with the angles formed by their sides, will be found very useful :—

No. of Sides.	Names.	Angle at B A C, Fig. 1,162.	Areas.
3	Trigon	30	0·4330127
4	Tetragon	45	1·0000000
5	Pentagon	54	1·7204774
6	Hexagon	60	2·5980762
7	Heptagon	64$\frac{2}{7}$	3·6339124
8	Octagon	67$\frac{1}{2}$	4·8284271
9	Nonagon	70	6·1818242
10	Decagon	72	7·6942088
11	Undecagon	73$\frac{7}{11}$	9·3656399
12	Duodecagon	75	11·1961524

Before we can properly understand the ellipse, it will be necessary to examine cylinders and cones. These, therefore, will be our next subject.

Cylinders and Solids.

A cylinder is a solid body, as at A B C D, Fig. 1,165. (The plumber has a great deal to do with hollow cylinders, for nearly all pumps, barrels, and valves are of this shape, some cisterns also are made cylindrical, to say nothing

FIG. 1,165.

about pipes.) It may be conceived to be generated by the motion of a circle, which is in a direction perpendicular to its own surface, and parallel to itself, and if right, at right angles to its own plane.

FIG. 1,166.

All cylinders are either right or oblique according to whether the axis is perpendicular or inclined.

A section of a right cylinder, if taken at right angles to its axis, must be a circle, and if hollow the two sides would form concentrative rings, as at Fig. 1,109 ; but if cut obliquely to its axis it forms an ellipse, as at A B C D, Fig. 1,166, also at Fig. 1,167. Fig. 1,165 shows the cylinder as cut from E to F. Fig. 1,166 shows a part side view, and Fig. 1,167 shows a front view. Now, if you

FIG. 1,167.

examine this carefully you will see that here is the true ellipse, and on further examination of these figures and by continuing the line E F, Fig. 1,165, you observe the roof line.

You should give these figures your most careful consideration and study, as they will demonstrate to you the easiest method of cutting anything you may require.

To find the solidity of a cylinder. Multiply the area of the base by its height, and the product will be the solid contents (see Problem 36, and circles).

To find the surface of a cylindrical pump-barrel, tank, etc. Multiply the circumference by the length, and the product will be the surface, of inside or outside, according as you may measure for. If you also require the sides and two ends, then, of course, you must add the area of the two ends.

Cones and Conic Sections and Solids.

A cone is a round pyramid, or solid, having a circle for its base, and terminated by a point called the vertex, or

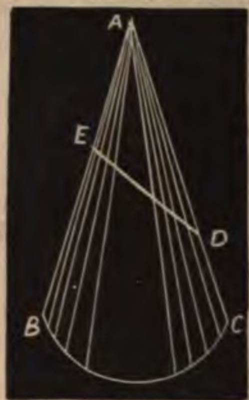


FIG. 1,168.

apex, of the cone. It may be conceived to be generated by the [illegible] a right-angled triangle about its perpendi[illegible] 1,168.

A line drawn from the apex to the centre of the base is the axis of the cone, and when this line is perpendicular to the base, the cone is called an upright or right cone, but when inclined, as at Fig. 1,169, it is called an oblique cone.

FIG. 1,169.

Cut Fig. 1,168 through the axis from apex to base, and the section will be a triangle. But if you cut it by a plane at right angles to the axis, the section will be a circle; and if you cut it obliquely to the axis, and quite across as a right

FIG. 1,170.

line from one side to the other, as at E D, Figs. 1,168, 1,170, and 1,171, this section is an ellipse, and the same as the section of a cylinder. See Figs. 1,165, 1,166 and 1,167. This, at first sight, may appear strange, that a cylinder

FIG. 1,171.

and a cone should, when cut obliquely, form an ellipse. Ordinary observers would suppose that the cone being cut obliquely would form an oval; they frequently imagine that it will be wider at one end than the other, or the shape of an egg, *which is an oval.* N.B.—You should be particular about this, as the oval and the ellipse are distinct from each other.

If you cut the cone parallel to one of its sides, as at A B C, Fig. 1,172, then the section will be a parabola.

FIG. 1,172.

This curve is used in computing the force of air or steam in cylinders, air-pumps, &c.; but this is not our work, and for it see works on Steam Engines.

If the cone be cut so that the section is parallel to the axis, the curve is then a hyperbola, as at A B C, Fig. 1,173.

FIG. 1,173.

These diagrams are known as conic sections. There are different kinds, namely: triangular section, as at Fig. 1,169; circular, as at A B, Figs. 1,171 and 1,174; ellipse, when

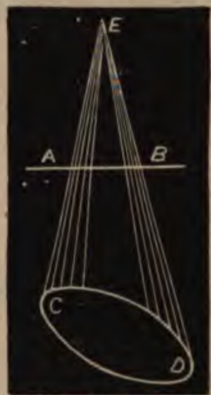


FIG. 1,174.

the plane cuts the cone obliquely and passing th two sides, as at E D, Figs 1,168, 1,170, 1,171; when the plane cuts the cone parallel to one side, as Fig. 1,172; and hyperbola, when the plane cuts so that it will neither meet nor come parallel opposite side, as shown at A B C, Fig. 1,172.

Q

For the method of cutting the envelopes or covering for cones, see my works on covering cones in Plumbers' Work.

To find the surface of a cone. Multiply the slant height by half the circumference of the base, and the product with the arc of the base will be the surface.

To find the solidity of a cone. Multiply the area of the base by one-third of the height, and the product will be the solidity of the cone.

As we have just found out the method of cutting cones to form ellipses, &c., we cannot do better than examine the different methods of striking them on paper, &c., as this will form an important part of plumbers' geometry.

Ellipses.

After what we have seen of cutting cones and cylinders to form ellipses, we may be inclined to ask what a true ellipse is. Can a true ellipse be drawn or struck with the ordinary compasses? No, it cannot; for in the true ellipse there cannot be any part of a circle, neither can there be any part of a straight line. It is formed with four curves, three of which commence at the point where the first terminated, so that in order to strike this figure you must have movable centres or their equivalents.

I am fully aware that some writers have recorded that a circle is made up of a number of straight lines, and if you accept this theory, then you may also take it the ellipse is formed with a quantity of circles, or, more correctly speaking, segments. We will compare the figures struck with the compasses, and the ellipse struck properly.

Problem 43.—Fig. 1,175. The simplest and proper ellipse is that struck with the trammel, or the ellipsograph, or the elliptic compasses, as shown at Fig. 1,175. This is

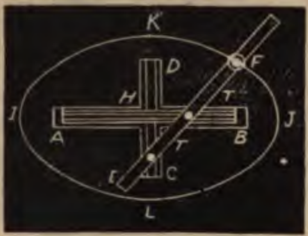


FIG. 1,175.

a very useful instrument for drawing an ellipse. The important parts are the right-angled cross A B C D, which is grooved to receive the two studs fixed on the beam or tracer T T. This tracer is provided with a pencil, as at F, which, of course, may be adjusted at will. It works as follows:—A B are the major axes and C D the minor. Now begin by first laying the cross of the trammel on the major and minor lines, then adjust the sliders of the tracer in the grooves so that the pencil touches the major and minor axes, you may then move the tracer round the elliptical path as the pins or studs slide in the groove, taking four strokes to one revolution, and you will have an ellipse.

You observe that as you push the tracer round, so you shift the centres by causing them to slide up and down the groove; of course, the two studs are a fixture on the beam or pointer, after the lengths of minor and major axes are obtained. Perhaps you will better understand this by the following primitive apparatus:—Nail two pieces of 1in. square wood together cut down at H, Fig. 1,176. So that it may be level, fix these pieces on the boards, then take a piece of the same kind of wood and make the pointer K L. Fix two bradawls at C D and another at P. Here P is really the pointer, being longer than C D. Now place the pointer as shown. Keep the bradawls C D close up to the wood, or cross and work round the pointer P, from G to E, which will give the required curve; repeat this for the other

FIG. 1,176.

three curves, and you will have a complete ellipse. We have another kind of trammel, known as Bowley's trammel, which is exceedingly useful for office work.

Problem 44.—Fig. 1,177 shows a simple and much used method of striking the ellipse with a string and pencil, as follows:—Having the two points on the transverse axis A B given and set, we next proceed to set out the conjugate axis C D, forming a cross or square; then with the compasses take half the transverse axis, and from the point C on the conjugate axis describe the arc E D F, or, set off the

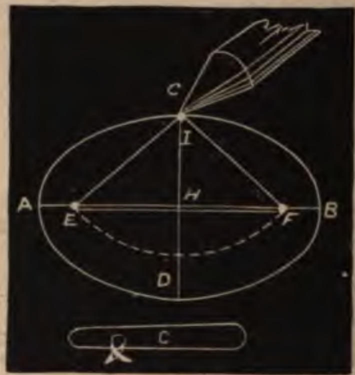


FIG. 1,177.

distances or points E F, and fix two pins on these points for the purpose of holding the string G, the ends of which are tied together to form a loop, which, when stretched over the two pins and up to the point C, will form a triangle. Now take a pencil, and with the string stretched over the point and also over the two pins, describe the ellipse.

Problem 45.—To determine the centre of a given ellipse, also the transverse and conjugate diameters.

In this diagram, Fig. 1,178, draw any two parallel lines across, as at O N and M L, cutting the curve. Bisect these two lines, and draw the line A B, cutting the curve at A B. Bisect this line, which will give the centre P. Now upon P with any radius at P, L M N O describe a circle, cutting the ellipse at the four points L M N O, and with a right line join these points as shown. Bisect these lines and you will have the transverse axis (in this case *shown* one line will be upon the other, as the figure will be again required). Next, through the centre P, draw C D parallel to the line L M; this will be the conjugate axis.

You will notice that in Fig. 1,178 the parallel lines are at equal distances from the major points, but they may be taken at any part.

Parts of the ellipse defined. See Fig. 1,178.

Transverse axis, A B.

Centre of ellipse, P.

Conjugate axes are the transverse axis bisected, as at the extreme points C D.

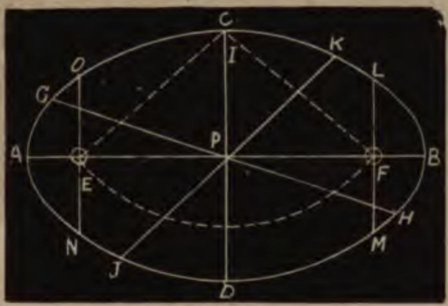


FIG. 1,178.

Foci of the ellipse are the two points E and F.

Latus rectum is a right line L M or N O, passing through the focus of the figure at right angles to the transverse axis.

Parameter is the latus rectum, or *vice versâ.*

Diameter is a right line passing through the centre, as at J K or G H.

The double ordinate is a line drawn through any diameter parallel to a tangent at the extreme end of that diameter, and terminated by a curved line.

Problem 46.—Fig. 1,179. This figure will show plainly what the ellipse is. If you take two semi-circles and divide them both into the same number of equal parts, as at 1, 2, 3, 4, 5, and then to the points draw the perpendicular lines on the large circle, and then draw the horizontal lines on the points of the small circle, the points where the lines intersect will describe an ellipse very plainly.

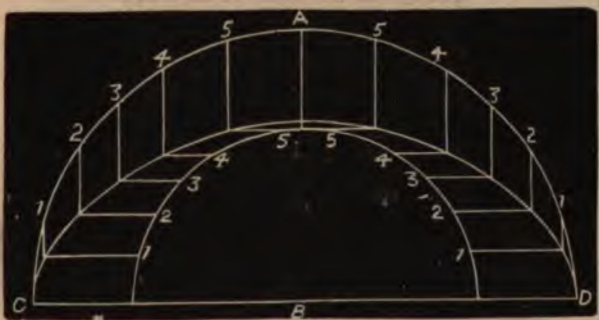


FIG. 1,179.

Problem 47.—To draw an ellipse in a given square, or drawing an ellipse with diagonal lines, Fig. 1,180.

Let A B C D be the given square, and let the lines be divided into the same number of equal parts or points as shown, draw right lines from the points as shown, and the intersecting points, as at H G F, will give the required curve as traced on bottom part of figure.

Having given several methods of striking the ellipse, I may now describe a method as practised in some workshops with the compasses, but which, of course, being struck with compasses, is not a true ellipse.

FIG. 1,180.

Problem 48.—The elliptical substitute, the major axis only being given, Fig. 1,181.

Let A B be the major axis. Divide this into three equal parts A C D B. From C and D as centres, with C A as a radius, describe the equal circles A D C B, cutting each other in the points E F. From E and F as centres, with a radius not larger than that which encompasses the equal circles as at G, strike the arcs G H I J, which will cut the circumference of the same circles, and complete the figure.

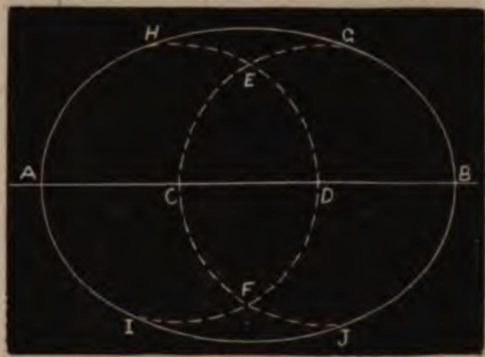


FIG. 1,181.

Problem 49.—Concentric ellipse, *substitute* suitable for showing the plan of elliptical pans, &c., &c., Fig. 1,182.

FIG. 1,182.

Draw the line A B, take any two points, as at C D, on this line and construct two equilateral triangles

C D E and C D F, base to base, and produce their sides F D indefinitely, or to H and E D to I, and E C to J. Through the vertices of these triangles draw the line F E, intersecting the line A B at K. Next take any point L or P (the width of the ellipse) of equal distance from the centre K, then from E or F as centres, with the radius F L, describe the arc O L R, then from E as centre strike the arc T P S, and from C or D as centres, with the radius of C Q T or D R S, strike the small arc R V S or Q X T, which will complete the inner arcs. For the outer arcs take points in the line F E further distant from L and P, using the same centres.

Problem 50.—Fig. 1,183. To find the centre of an ellipse, also the arcs, or transverse and conjugate diameters, the circumference being given.

Draw any two parallel lines across the figure, as at A B and C D, cutting the curves as shown at A B, C D. Next bisect these lines as at F E, then through the intersecting points

FIG. 1,183.

F E, draw the line G H. Now bisect G H at I, and this will be the centre of the ellipse.

To obtain the transverse and conjugate diameters take I as a centre, and with any radius, as at I V, describe the circle V J K, &c., cutting the ellipse curve in four points, as at J K, &c.; now with the line join M L and J K, and bisect these lines as at O N. Through the intersecting point O and the point I draw the line P Q, this will give the transverse axis. Now draw the line V B through the centre point I and parallel to the lines M L or J K, and this will give the conjugate axis.

Problem 51.—Fig. 1,184. Oval or egg-shaped figures, suitable for drains or sewers, water closet seats, &c.

First strike the line A B and bisect the same, strike the line C I, and from C as a centre, describe the circle A I B D; through the points A D draw a line, extending it indefinitely, also from B to D draw a line, then from the point A, with the radius A B, strike the arc from B to F, also from B as a centre strike the arc A E; next from the point D, with the radius D F or D E, strike the small arc E F, which will complete the figure.

Should you require to make the figure shorter or longer, you may do so by contracting or extending the point D to J, and also extending the lines A D and B D along the conjugate axis, as at L J, K J; but when extending this diagram you must bear in mind that from A to K must be wider, or at a greater distance than from D to J. Now proceed as in the first case. Perhaps I had better further explain. Suppose you require the figure longer, then produce the line from A to L and B to K, of course at equal distances, and extend the line from D to J. Draw the

FIG. 1,184.

line K J, L J, *which must be shorter than* A L or L A, then from L as a centre, with a radius of L A, describe the arc A H, cutting the line K J, and from A as a centre describe the arc B J, cutting the line J L; next from J as a centre, with a radius of J R, describe the small arc, which will complete the figure.

If you look carefully at this figure you may again trace it to be the same method of work as Fig. 1,182. This last method of striking the egg-shaped oval is now much used in drain work. It is what is known as the new form of oval sewers or drains, and the following are the proportions to be strictly observed. Let the vertical height J I, Fig. 1,184, be one and a half times the transverse diameter A B, and the radius of invert J H to equal one-eighth of the transverse diameter, and the radius of the sides B G to be equal to $1\frac{1}{2}$ times the transverse diameter. This is the idea of Mr. John Phillips, C.E., and further particulars may be had by referring to Mr. Baldwin Latham's work on Sanitary Engineering.

Another method simplified. Fig. 1,185 illustrates a simpler struck ovoid. Draw a line the diameter of

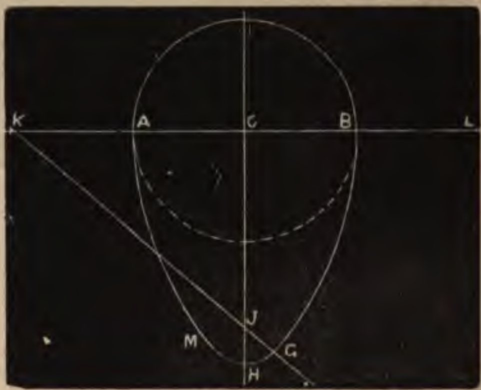


FIG. 1,185.

the ovoid, and strike the semi-circle A B. Bisect the line A B and draw the right line I H longer

than the length of the ovoid, set off the points L and K at equal distances from the points A, B, and from these points draw lines as at K, G, also from L to M. Now from L as a centre, with the radius L A, strike the line A M, and from K with the same radius strike the line B C. Now with the point J as a centre, and the radius J G, strike the arc G H M, which will complete the figure.

Fig. 1,186 is a very good method to adopt for striking ellipses, it enables you to get the curves of any sized oval without much trouble, and is struck as follows:—Let the line A B be the length, and H D the width, which must be perpendicular to the line A B. From the point B, with the width as at H D, set off the point E; next divide A E into three equal parts, and set off two of these parts on each side of the centre point Q, as at J K. From J and K as centres, with the radius J K, strike the curves

Fig. 1,186.

I J C and C K I, cutting each other at C and I; from C I draw the centre line. Now from the minor point H and point K draw the line K H, also from J to the minor point D draw the line J D, also from K I draw the line K D, and from H J draw the line O H. Now take K as a centre, and A K as the radius, and strike the arc Q A L, also from J, with J B as a radius, strike P B O. Now with I as a centre, and with the radius I Q, strike the curve Q H P, and from C as a centre, with the same radius, strike the curve L D O; this completes the figure.

If you compare the diagram Fig. 1,188 with the above you will see a wide difference in the two ellipses; the one is bull-nosed whilst the other is more pointed. Measure at A R, Fig. 1,186, and take the distance from Q to L and compare it with the distance on the curve 7, 7, Fig. 1,188.

Another method. Here the ellipse is to be constructed within a given square, and the width is as 6 is to 9. Let P a R S, Fig. 1,187 be the given square. Draw the major axis A B, then the minor axis C D perpendicular to A B, all four points cutting the sides and ends of the square. Draw a diagonal line from point A to point D, next measure off the distance A G, and from the point A set it off along the line A D cutting this line at a, also with the radius G C, from the point A as a centre, set off the point b, now divide the line between a b as at e, and from e as a centre, with a distance wider than half the distance between e and A, strike the arc g h, also with the same radius, but from A as a centre, strike the arc k v, next through the intersecting points E, H, draw the line S H E, continuing the same until it cuts the minor axis at C. Next measure off the point where the line H C cuts the line A B near E, and transfer this distance along the line A B, cutting it at F; now from points D and F draw the line K D, also from points D, E draw the line J D, also from C F draw the line C L. Now from the points F and E as centres, with the radius F B, strike the major curves K B L and J A H, and from the points D and C, with the

Fig. 1,187.

radius D J, strike the minor curves K C J and H D L. This completes the ellipse with proportion as 6 is to 9. Fig. 1,186 is the best plan to adopt, because in Fig. 1,187 you are restricted to the proportion 6 and 9, otherwise 6 in width and 9 in length.

Another method. Let P D, Fig. 1,188, be the transverse diameter and J L the conjugate diameter, which must be perpendicular to P D. From J or L, with the radius P K, describe the arcs cutting the line A D at B 5 and A 5; these arcs form the foci of the ellipse. Next divide the two portions of the line from A to K and K to B into any number of equal parts (viz., 5 and 4 on each line should be the same distance between each other), say 5 parts, but, of course, for larger ellipses take more parts, and if these parts are lessened in ratio as they approach from 1 to 5, there will be an advantage; let these parts be numbered as shown, from 1 to 5 on each side of the centre. Now from A 5 with a radius P 1, P 2, P 3, P 4, and lastly P 5, describe the arcs between J and P, also between P and L. Serve the other side the same. Now from B 5 as a centre,

Fig. 1,188.

and with the radius from D to 1 a, strike the intersecting arcs X, X; next, with a radius from D to 2 b, still using B 5 as a centre, strike the intersecting arcs 9, 9; next, from B 5 with radii D 3 b, D 4, D 5 A, still using B 5 as a centre, strike the remaining intersecting arcs 8, 7, 6 on the lines P J and P L; serve the other end of the ellipse in a similar manner, but using A 5 as a centre, then draw lines through the intersections as at J P and P L; this will complete the figure.

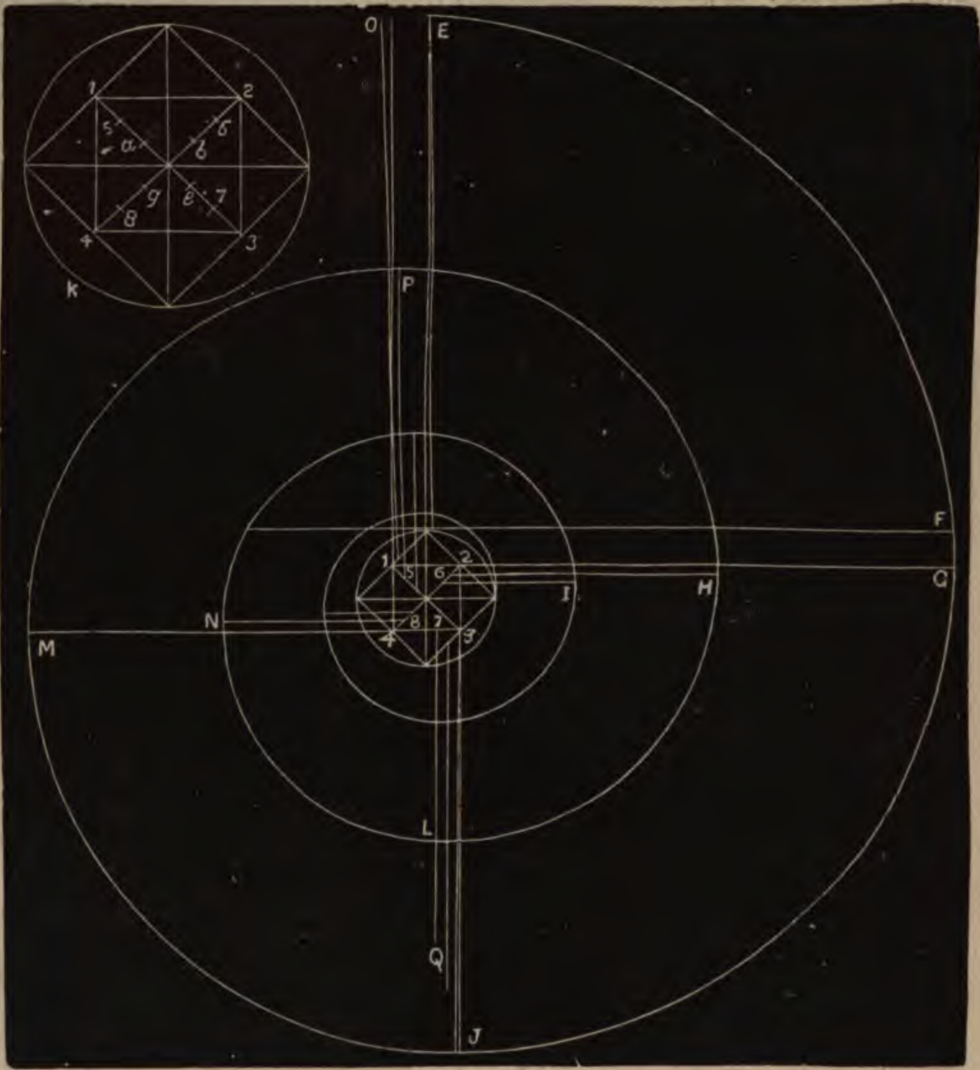


FIG. 1,189.

I have described these ellipses at length because the painter is often called upon to strike them out to suit circumstances. For instance, sometimes it is required to paint an ellipse on shutters or walls for writing on, also for decorations in drawing rooms, &c., no two places being in the same proportion. (I insert this as the plumbing and painting trades are closely in touch with each other, especially in country towns, where I know this will be useful.)

Spirals.

The greatest diameter being given, strike a vertical line as at E, Fig. 1,189, and bisect it, then divide this vertical line above the bisecting point into four equal parts, as at O P, &c., Fig. 1,189, also divide the lower part of the vertical line into four equal parts, as at Q L, &c. Next take one of the four equal parts as a diameter, and with half this as a radius, using the bisected line as a centre, strike a circle as at 1, 2, 3, 4 (also see enlarged circle as at K), this will give you the eye of the spiral. Next inscribe a square as at 1, 2, 3, 4, and draw its central diameters, as shown at 1, 2, 3, 4, in the enlarged circle at K. Now, as shown in the enlarged diagram, divide each diameter (or the diagonal lines from corner to corner in the smaller square) into six equal parts, commencing from the top corners as a starting point, and number them (as shown in the larger diagram) 1, 2, 3, 4, 5, 6, 7, 8, a, b, c, d, &c. Here you will see that I have commenced at the top left-hand corner, and proceeded from left to right. Having marked 1, 2, 3, 4 next upon the diagonal lines 1, 3, 2, 4, which is divided into the six equal parts, mark as shown from left to right the figures 5, 6, 7, 8, after this the letters a, b, c, d.

Having the circle and squares marked out as shown in the enlarged figure K, proceed to make the spiral as follows:—From point 1 as a centre, and with a radius of from 1 to E or 1 to O (the extreme point of the four equally divided parts), describe the arc E G, now draw a line through points 1 and 2, extending it to G; next from point 2 as a centre, and with the radius 2 G, describe the arc G J, now draw a line through points 2 and 3, extending it to J; next from 3 as a centre, with the radius 3 J, describe the arc J M, and draw the line M through the point 3, 4. Next, from 4 as a centre 4 M, strike the arc M P, and again proceed as above from the centres 5, 6, 7, 8, and when round begin striking again on the points a, b, c, d, and so on, according to the number of parts to which you have divided the original perpendicular line.

Spirals and Curves.

We have in our last figure further described the spiral, which in shape materially differs from those preliminary figures described. Of course, many of my readers have seen spirals blended with other geometrical outlines, such as is shown in the Grecian scroll truss, also in the Elizabethan scroll truss, and also as shown in the bottom part of the Grecian ornament known as the honeysuckle. Let us examine the scroll, Fig. 1,190. Here two spiral ends are fixed between the ogee lines H J E and L N M, and so a scroll is geometrically produced and with the greatest possible ease. To produce this without the aid of compasses would require much practice, but by working the diagram with the aid of tools the thing can be at once easily produced,

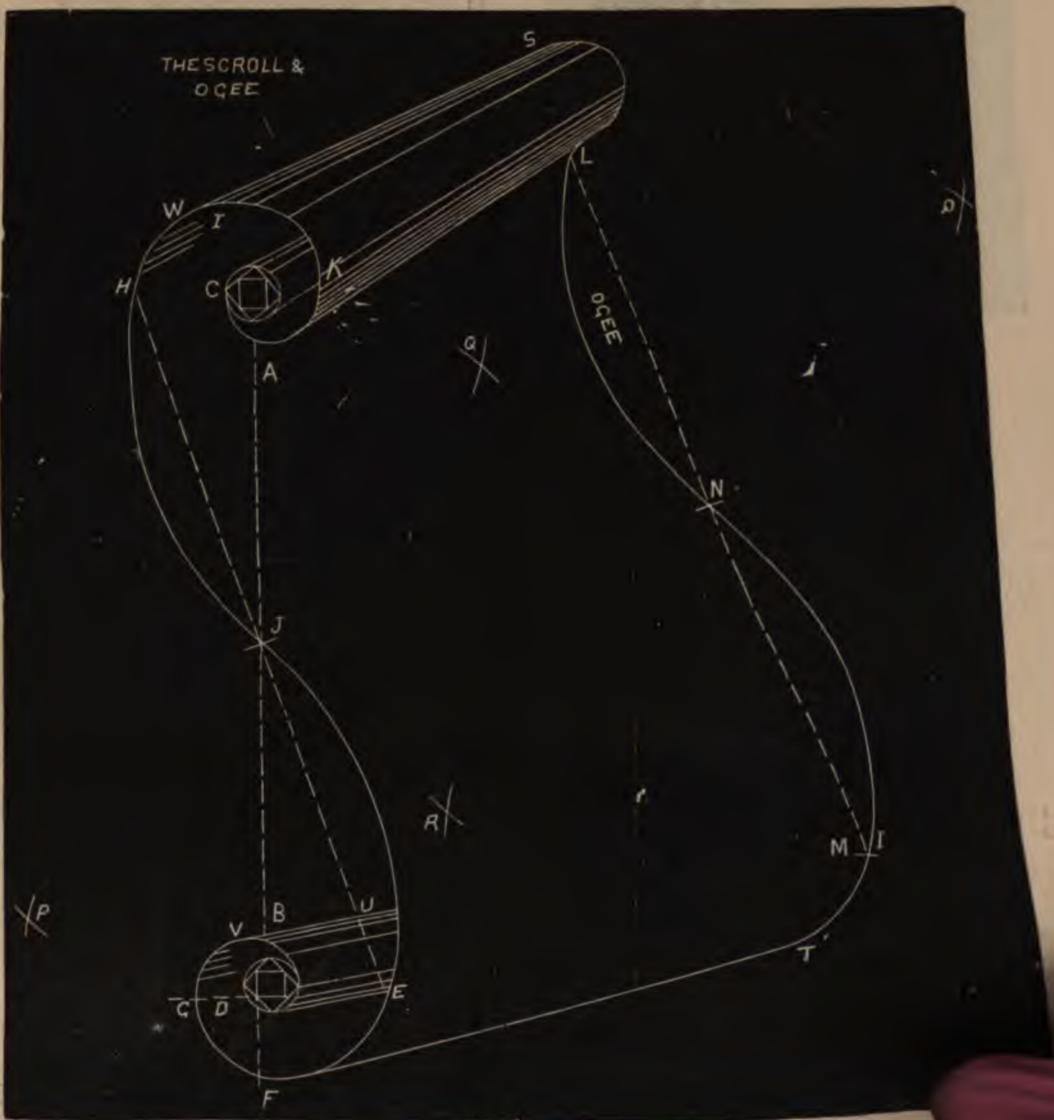


FIG. 1,190

and quite near enough for all practical purposes; this will be found a most useful problem, and as I wish my reader to be useful at all times and under any conditions to himself, and *useful to others*, I cannot do better than now to proceed to describe a few good, simple, and useful geometrical rules suitable for all classes of men likely to read this work.

This scroll, Fig. 1,190, is, as may be seen, made up with the spiral curves described at Fig. 1,189 and the ogee. (The ogee is used in rain water heads, see Fig. 1,204.) Therefore, before I can further explain the scroll figure, I must describe the ogee, for this see Fig. 1,191. To strike this, first with a line join the projecting point B to the

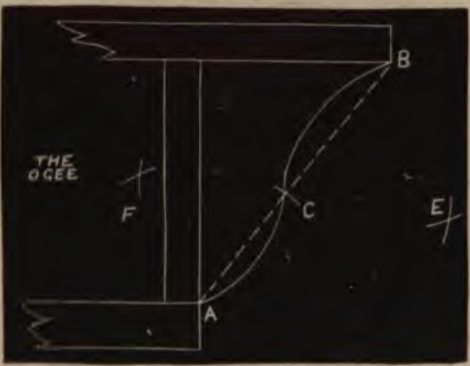


FIG. 1,191.

recess A, and bisect this line at C; next, with the distance A C, and from the points A and C as centres, strike the intersecting arcs F; next, from the points C, B, with the same radius, strike the arcs E, and from E and F as centres, with the same radius, strike the arcs C B and C A, which will complete the ogee.

Now turn back to the scroll, Fig. 1,190, and first strike the spirals (which may be of different sizes) C K I and D V G F, and from the points H and E, strike the ogee H J E; the other side may be done in a similar manner, which will complete the scroll. This figure gives you a beautiful trade sign or board device for name, &c.

Reverting to the ogee, Fig. 1,191, I wish to say that it may be struck in more ways than one. For instance, the line A B may be bisected as at C, or it may be otherwise divided. Say that you wish the space between C and B to be less, say half, all that is required is to determine your size and open the compasses to the distance, and from the points, as before, strike the intersecting points as at E and F, and work as before. Or it may be that you will require the space between A and C to be a hollow, the hollowed or reversed part B C to be rounded, then, if so, strike the arcs E and F the reverse sides to which they are shown.

Before I can proceed further with the work it will be necessary for me to describe and illustrate a few mouldings, &c., such as the fillet, torus, the Roman ovolo, the Greek ovolo, &c.,

Plumbers, when executing ornamental work, such as rain water heads, finials, and such like, will find the method of making drawings of mouldings of great help.

The regular mouldings are eight in number, and are named as follows:—The fillet, or band; the torus; the astragal, or bead; the ovolo; the cavetto; the cyma-recta; the cyma-reversa, or talon; and the scotia, all of which are more or less employed in the building trade.

The fillet is simply the smallest rectangular member in any composition of mouldings, and if it stands on a flat surface, the projection should equal its height. The fillet is often used to separate other members.

FIG. 1,192.

The torus. This is illustrated at Fig. 1,192. A C is the back from which the torus A B projects. The torus is something like a bead and answers the purpose of the astragal, though the latter is employed in work of a smaller kind. The torus is often employed to give a finish to curbs, and sometimes it is formed by simply nailing a piece of quartering on the curb with the face slightly rounded so as to form a nosing, with an undercut to form a kind of roll. See torus rolls in my Roof Work.

The Roman ovolo (used in rain water heads) is a kind of quadrant, and is illustrated at A B and A D, Fig. 1,193. In A B C the height is equal to the projection. Draw A B at right angles to A C, and from A as a centre, with the radius of A B, strike the quadrant B C, which will give the contour of the ovolo. But should you require to make your ovolo with less projection than its height, you may do

FIG. 1,193.

so as follows:—Draw P J D as before, and the line P J at right angles. D P is the height and P J the projection. From the point D as a centre, with the radius D P, strike the arc Q, and from J as a centre, with the same radius, strike the intersecting arc Q, which will give the centre of the ovolo, and from Q as the centre strike the contour of the ovolo J D.

The cavetto (used in rain water head work). This is illustrated at Fig. 1,194, and is the reverse of the ovolo. It is often employed as a finishing, and is also employed where strength is required, and frequently in entablatures; and in the R[illegible] order it forms the crowning member of the corr[illegible]e, or shelter and shield the under members [illegible]ed in bases or capitals. The cavetto i[illegible]ar manner to the Roman ovolo,

the striking centres being obtained at C and H, Fig. 1,194, B E being the radius, and A, B the centres for striking the centre arcs C, &c.

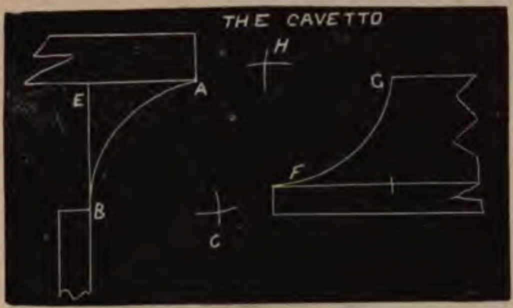


FIG. 1,194.

The Greek cavetto differs somewhat from the Roman, inasmuch as the former is of a more elliptical shape, and therefore when striking this figure two or more circular arcs must be employed as follows, see Fig. 1,195. Let B O be the projection of the moulding, and D O the vertical line. Draw the line B Q parallel with A O, and make this line in length to equal two-thirds of the projection O B, and from

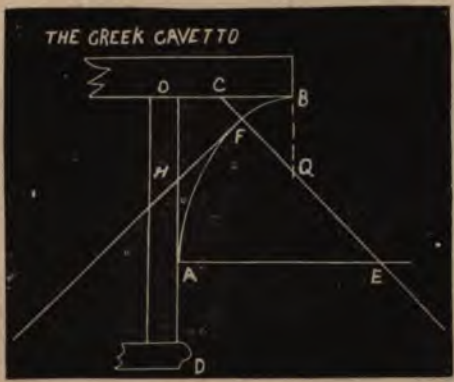


FIG. 1,195.

the points C Q, draw the line E C Q. Next from the point of the line at Q as a centre, with the radius Q B, describe the arc B F; now from the point F draw a line F H perpendicular to the line C Q E, cutting the line O A at H, and make H A equal in length to H F, and draw the line A E perpendicular to A O, cutting the line C E at E, and this point E will be the centre for striking the arc F A, which completes the contour B F H A of the Greek cavetto.

Curves.

The conge or scape. This is a species of cavetto, but it is not one of the regular mouldings. In some orders it is used for joining the capitals and bases to shafts or pipes. B C, Fig. 1,196, is the projection from the back or vertical line A B, and if the projection is to equal the height of the curve make B F to equal B C; and from the points C and F as centres, with the radius C B, describe intersecting arcs at F, and from F as a centre strike the arc

FIG. 1,196.

F C to complete the contour of the conge. The conge is used in rain water heads and bases of finials, fountains, &c., and may be less than a quarter of a circle, as at Fig. 1,197,

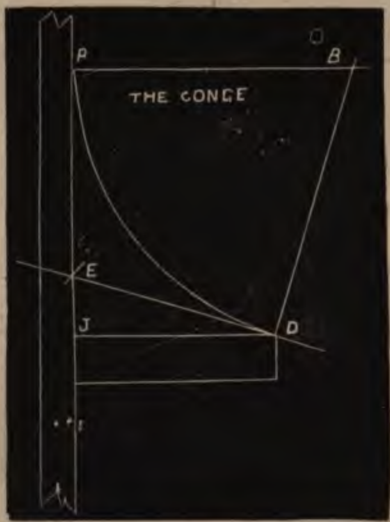


FIG. 1,197.

and is struck as follows:—Let J D be the projectio
E D a line, which will form a tangent with the curve at D. From this point draw the line D B perp to the tangent line, then measure the line from D set this distance on the vertical line, as from E t. from P draw a perpendicular line P B cutting the li then from point B, with the radius B P, strike the .. of the moulding as at P D.

The Scotia.

The extremities of the curve being given, as at B A, Fig. 1,198, draw the perpendicular lines B F and A D, and then the horizontal line A; take one-half of the line B F, and two-thirds of the line A F, and add these lengths together, this will give the distance from A to G. From G as a centre, with the radius G A, describe the semi-circle D E A; next draw the line D B E through the points D

FIG. 1,198.

and B, then from the centre point G draw the line G C E, cutting the line B C at C; then from the point C, with the radius C B, strike the arc B E, which will give the contour B E A of the scotia in conjunction with the curve of the large semi-circle.

The Greek Cyma-reversa or Talon.

This is represented at Fig. 1,199, and is drawn as follows:—With a right line join the points A, B, bisect

FIG. 1,199.

this line at H, next bisect the line A H and B H, and with half as the radius strike the arc A E H and H K B. Next, from any number of points in line A H and H B, draw perpendicular lines as at E, also as shown at J K, meeting the circumference of the circles, and from the points as at J, draw horizontal lines *equal in length* to the before-mentioned corresponding perpendicular lines, as from I J

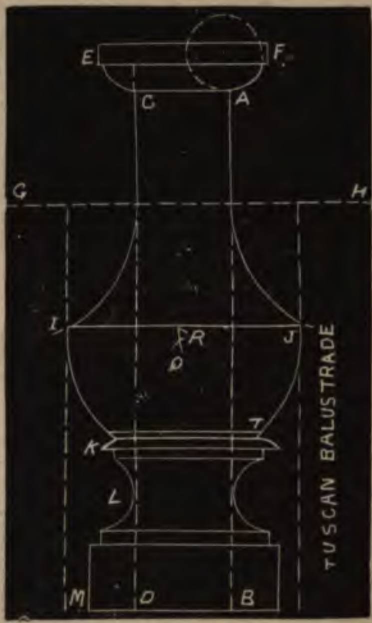


FIG. 1,200.

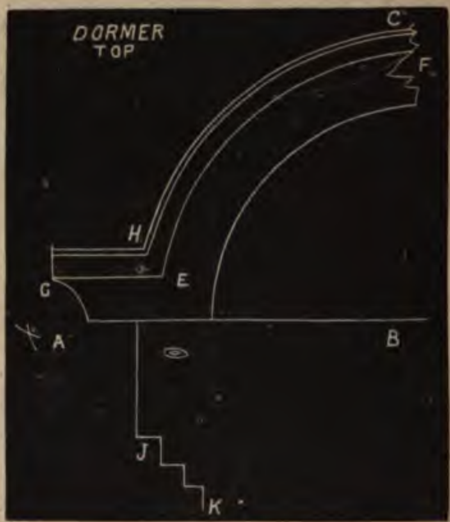


FIG. 1,201.

and J K, &c., and then a curved line drawn through the extreme points of these lines, as at H I B and A F H, will give the required contour of the moulding.

I have described and illustrated sufficient of the mouldings for our work, therefore I will now proceed to explain their

use. We have seen how the scroll, Fig. 1,190, is made up: it is simply the spiral and ogee curves put together; this

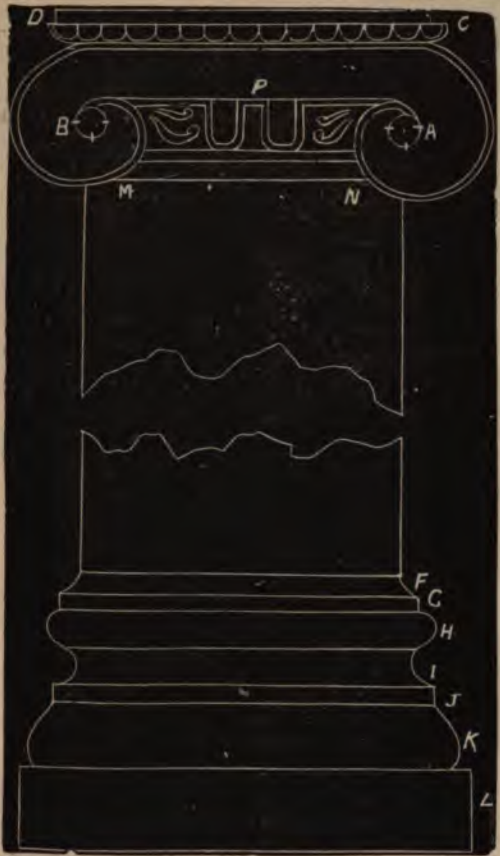


FIG 1,202.

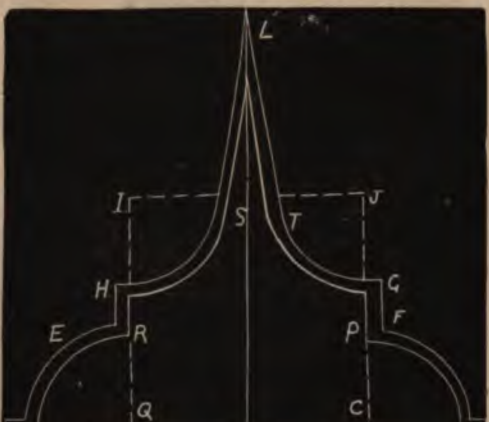


FIG. 1,203.

being the fact, let us examine Fig. 1,200. This is a Tuscan balustrade, and consists of a few simple right lines, curves, and mouldings, such as just described, which I shall now leave for a little while to my readers to work out having given them the general points to work from. (See Roof Work.)

Now let us examine the dormer top, Fig. 1,201. Here is another very simple figure, and will be found very useful; the parts are too simple to require comment.

Fig. 1,202 is the Ionic capital, showing the spiral and most of the mouldings used in architecture.

Fig. 1,203 illustrates the Elizabethan gable. It is also used for the tops of summer houses, &c., and will form good practice for the plumber and also the zinc-worker. All the points are given for striking as at I J, Q C, &c.

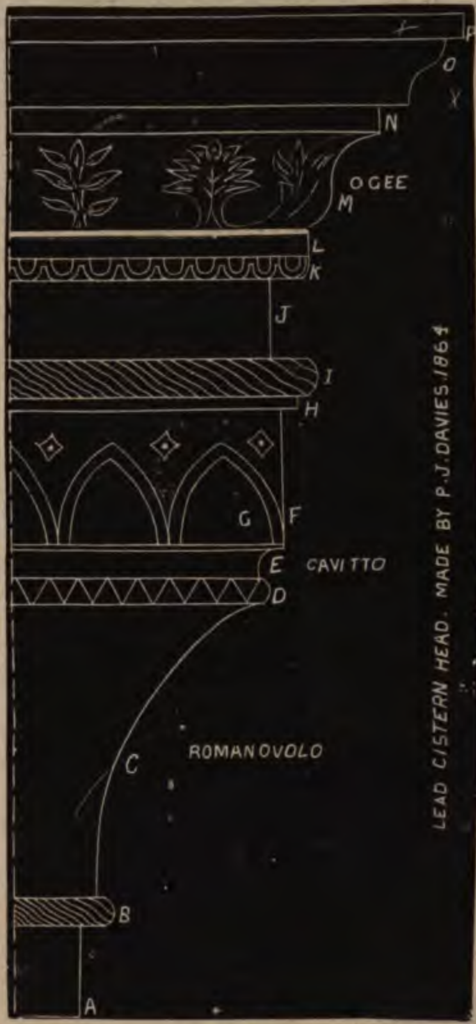


FIG. 1.204.

Fig. 1,204 illustrates the half of a rain water head made and fixed by the writer for the firm of Messrs. Jackson and Shaw, the then well-known London builders of the R Academy and Burlington House, Piccadilly, Knights Barracks, and many other public buildings, &c.

MECHANICS FOR PLUMBERS.

Hoisting or Pulling-up Lead.

Having cut all that you require, you must see about hoisting or pulling it up. This is no fool's play, but often

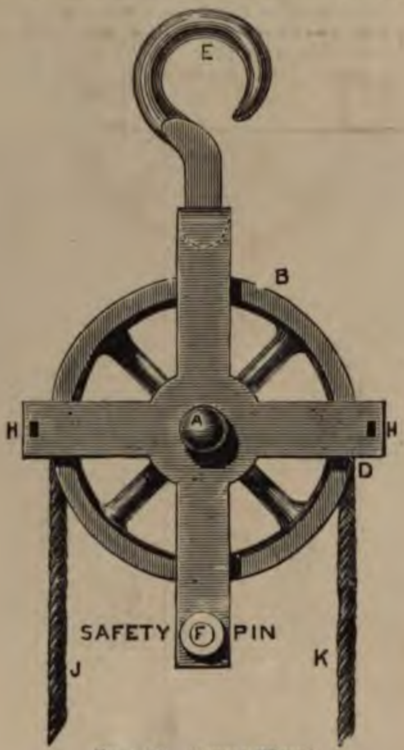


FIG. 1,206. (SINGLE WHIP.)

FIG. 1,207.

very hard work. One and all help if required, but it is generally the labourers' work, one or two plumbers assisting and looking after this job. First thing now required is a good new scaffold cord, a fall and pulley gin block or wheel. This is often called a snatch block, but it is not a snatch block that is wanted: that is a very different thing. This is used to save reeving (see the snatch block, Fig. 1,214), has an opening in one side or cheek, and generally shuts up with a hinge. The viol blocks and rouse-about blocks are much about the same kind of thing. The snatch blocks are too small; what we want is a pulley or gin block or wheel first, and after this we will have some other tackle. Figs. 1,206 and 1,207 are the kind of wheels we want at present. Now, having this fixed on a jib, which is generally made by throwing the butt end of a scaffold pole across a ledger and fastening it down to one of the joists through a window or through the roof, or by the use of a pair of sheer legs and the above pole, which arrangement is made by lashing two scaffold poles together at top with a good scaffold cord (any scaffolder will show you how to do this), let the jib pole be thoroughly fixed and elevated 10ft. or 15ft. higher than the landing stage; make a wreath (or reef, as known in America) for fixing on the end of the jib pole and hook on the wheel and reeve the fall, K, J (Fig. 1,206) through same.

FIG. 1,208.

Tieing On or Sending Up.

This is very important, and should be taken notice of. Fig. 1,208 is a timber hitch, but threaded through lead, and shows the proper but very simple method. To do this, first thread the rope through the lead, and let it come out at the bottom, as at A, about three times the length of the

roll; next take the end and pass it round the rope as at B, then thread it under as at D, then over and under again as at E, and another turn if you like—never less than two—and three or four twists for heavy pieces. This is the best and quickest way I can find, and after cutting up at least 5,000 tons of sheet lead (which is as near as possible the amount that has passed through my hands in thirty-five years) I can safely say that neither I nor any of the men working under me ever once met with the slightest accident from shifting or hoisting sheet lead. When I say 5,000 tons, I mean that this has actually been cut up or worked by myself personally, not as employer, or it may easily be trebled.

Measurings, Squaring, and Weight of Sheet Lead.

In order to hoist the lead, you should know what is the weight to be lifted. For this purpose we go to work as follows. The size of our pieces or gutters being 10ft. by 2ft. 4in., we proceed by duodecimal multiplication, sometimes called "cross multiplication," as follows:—

	10′
	2′ 4″
	20′
	3′ 4″
	23′ 4″
Weight per foot super	7′
Total	162 lbs. each gutter.

For this work we do not require the part of a pound. Here you see we have 163lbs. to lift; how many men shall we require to pull it up? Say a man can pull 40lbs., then we want four men—three at the bottom and one at the top; the one at the top to land it when up. When it is up and all ready for laying, be sure and not place too much on the scaffold at once, or too much in one place. You should have some one at top to shift it about—important.

Having these gutters up, next I want some bays up, 10ft. by 3ft. 6in. What will be the weight, it being 7lbs. lead?

10′
3′ 6″
30′
5′
35′
7′
254 lbs. each bay.

If you pull this up as before, what weight will you have on the end of the jib, to say nothing about the weight of rope and wheel? You will have just twice 245lbs., because the lead is 245lbs., and in order to pull the rope with it at the end over the wheel you must put exactly this weight on the other end, and a little more to overcome friction, &c., not counted. You see that is the fact. But now you know this, go back to the hoisting of the gutters, and tell me how two men may lift the gutters as easily as the four men, the two men taking just twice the time about it. There are two ways of doing this.

Compound Pulleys. Leverage.

You have seen two to use the single pulleys. We will now fancy that we want more power, and for this let us make use of the diagram or Fig. 1,209.

FIG. 1,209. (RUNNER.)

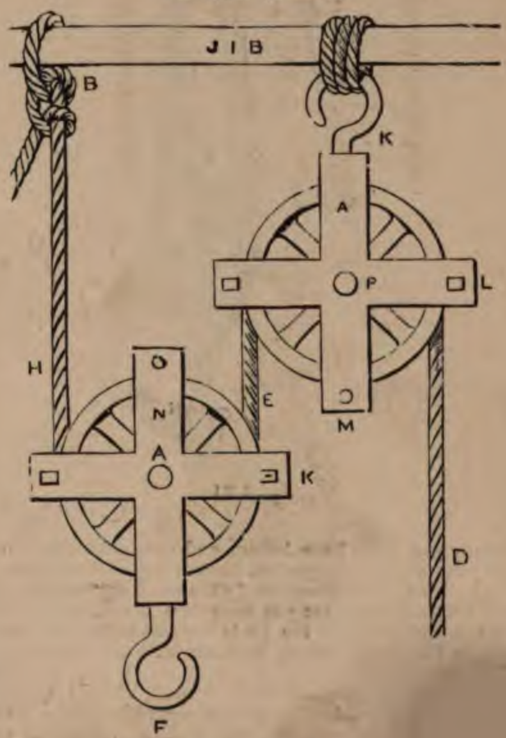


FIG. 1,210. (DOUBLE WHIP.)

Here you will see the same pulley reserved, viz., it is now a movable pulley with the one end of the fall or rope fixed as at B, Fig. 1,210.

Here it is plain that what strain you apply at E, will be transferred to H, and a pound at E, will be a pound at H, equalling two pounds at F; and in this manner your two men can pull or lift as much as four did before, with only half the weight on the jib. But here you work at a disadvantage. Another, or the second way, is shown at Fig. 1,210. In this way you require half as much again rope and another wheel; but there is an advantage,

FIG. 1,211.

because you pull from below, and can get more power over your work. Remember, however, that in power you gain nothing; you have exactly the same amount to pull, in fact a little more, for you have an extra lot of friction and the weight upon the jib is increased one-third more than in the first method, together with the extra wheel and rope.

I... t the use of the "crab," Fig. 1,222, you ... ıp lead to a very great advantage. You ... p with the wheel, A, Fig. 1,210, or you may use a set of blocks rigged as at Fig. 1,211, which will be explained shortly. But before we talk about blocks, let us understand the Fig. 1,210. Let us suppose that at F, we have a piece of lead suspended, the weight of which is 100lbs. What weight is required to be placed upon the end of the rope, D, to exactly balance the weight F? It requires just one-half, or 50lbs., because the rope passes over the movable wheel, A, and under the wheel, N, from thence round the jib, as at B. The effect of the rope going under the wheel is just the same as if you were sitting upon a swing, the weight of your body would be upon the two upright cords and equally divided. This being the fact, what weight have you now upon the jib? You know that on the cord at H, you have 50lbs., also upon the cord at E, also upon the cord at D; then there must be another 50lbs. added upon the jib, 50 at B, and two 50's at K, making in all 150lbs. This is very important, as you would look rather sheepish if you began to raise a sheet of 7lb. lead, whose weight is, say, 1,500lb., and you had reckoned your jib would only require to carry or bear this weight—which would be considered a good jib. This is one reason why you should, where practicable, adopt the system of blocks shown at Fig. 1,211, because for every wheel in the top block you reduce the necessary weight required to pull up the lead. The top block, D, is called the "standing block;" the bottom block, N, the "running block." The rope is called the "fall;" the fast end of the fall is the "standing" end, the other the "running" or "hauling" end.

When you want to separate the blocks by running out the rope, call this "overhauling the tackle." If you wish to bring the blocks together by hauling in the fall, this is termed "to fleet the tackle," or "fleeting the tackle."

A "single whip" is a block working as at Fig. 1,206, and is the simplest of tackle. "Whip on whip," or "whip and runner," are two single blocks, as at Fig. 1,212, one the "runner," E, the other the "standing," F. The fall of the standing is fixed to the runner, suitable for short ropes, &c.

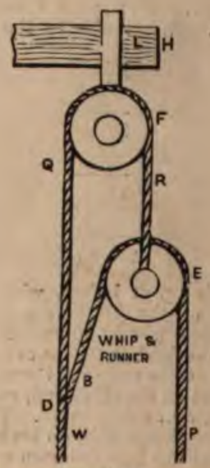


FIG. 1,212. (WHIP AND RUNNER

"Double purchase" are two single blocks, the one a fixed, the other a runner. Let the fall be made good to the eyelet, E, Fig. 1,213, then reeve same through the runner block, and back over the pulley of the fixed block; this gives double purchase.

Fig. 1,213 is the same thing as Fig. 1,212, except that Fig. 1,213 has two runners and one fixed pulley. The rope D, should be made fast to the pulley 3, as is the case with the rope on top of pulley 1. The rope from pulley 3, downwards suspends the weight.

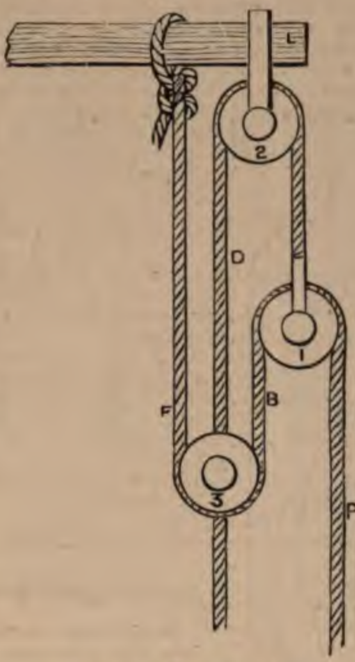


FIG. 1,213. (SPANISH BARTON.)

"Treble purchase" is the same thing as "luff tackle." This is a double block, as Fig. 1,215, and a single block, as Fig. 1,214. The fall is made good to the eye of the single block or runner at E, then reeved over the pulley in fixed block, back through runner, then over the second pulley in fixed block, and down the yard tackle.

FIG. 1,2'

fo

Fr

is the lock-line for opening the cheek so as to receive the bight of the fall, and to save reeving through cheeks; handy when using the crab.

Though Dynamics should be learned at school, I can safely say that not one plumber in fifty understands this important subject. As I wish all plumbers to become, as they should be, something out of the common order of workmen, I shall, for the benefit of the trade, here thoroughly, though as simply as possible, describe the whole system of pulleys, and that of the crab necessary for shifting or putting up a sheet of lead.

Single Whip,

Or the gin block, needs no further description, then let us turn to

Whip on Whip.

Fig. 1,212 allows you to use a short stout cord, fall, or rope, and a long light fall (often very important to those having short tackle) in combination; it also lets your work become lighter upon the hands. Almost any blocks can be used. The power gained is as follows:—First, there are in Fig. 1,212 two pulleys; E, receives a pressure from P, B, say 1 lb. on P, and 1 lb. on B, this gives 2lbs. on R, and also on Q, which also goes to the weight W. It follows that 1 lb. on P, will balance 2lbs. on W, that is if the end of the rope P, were attached to some stationary point. But that would be stupid. For lifting lead, fix it to the fall, or, of course, as low down as you can, like that shown at D; then you have another power equal to that at P; first you had 2lbs. pulling up the weight W, now you have 3lbs. This is a power multiplied twice, and one added equals three. If the end B, were a fixture, the end P, would then only travel two-thirds the space as when B, is portable. Be careful with this as you can only raise the weight in accordance to how you fix the end of the runner rope.

Everyone should know that there are three kinds of levers, termed respectively those of the first, second and third order. Fig. 1,217 is, if you bear down on the lever, a lever of the first order. If you go to Fig. 1,217, and pull

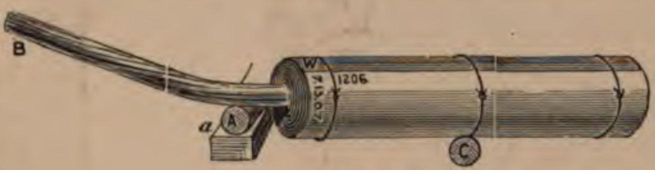


FIG. 1,217.

the lever B up, you have a lever of the second order. But if you place the lever D, at B, and then pull up at E, you have a lever of the third order. These orders are represented thus:—

Power	Fulcrum	Weight.
Power	Weight	Fulcrum.
Weight	Power	Fulcrum.

...hat is, the power is at one end, the weight at the ...he fulcrum between them. Second, power at ...um at the other, and the weight between ... 1,218, the weight is at one end, and the power between them.

FIG. 1,218.

Now, you know that there are three kinds of levers, so there are three kinds of pulleys—first, second and third. In the first order of pulleys, each pulley hangs by a separate cord, one end of which is fastened to a jib, L, Fig. 1,219, and the other to the pulley above it 4,3,2,1. In the second order of pulleys, the same cord passes round all the pulleys, which are arranged as at Fig. 1,212, one pulley being fixed, the other as a runner, which bears the weight. In the third order of pulleys, each cord is attached to the weight, as at F, H, J, Fig. 1,220.

You are now in a position to see and understand how these pulleys work; next see the power gained. Fig. 1,219 is the first system; 1, is the fixed pulley, the use of which

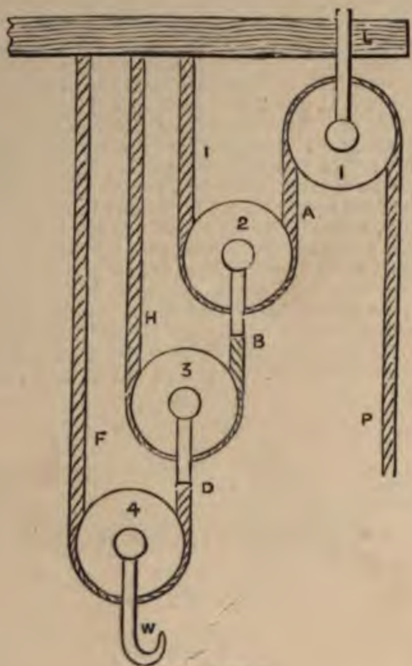


FIG. 1,219

is to reverse the fall. The power, applied to the end of fall P, is 1lb.; this strain goes through the fall to 1. The runner, 2, is now under strain equal to 2lbs.; in the same way we see that the fall B, has now 2lbs. strain upon it, also H, has 2lbs. This gives 4lbs. on the fall, D. Now, as this is continued to D, and F, this pulls 8lbs. on the hook, W, and if another pulley were added, this would give double for every pulley—16, 32, 64, and so on. If you multiply 2 by itself as many times as there are running pulleys, the result will be the mechanical gain.

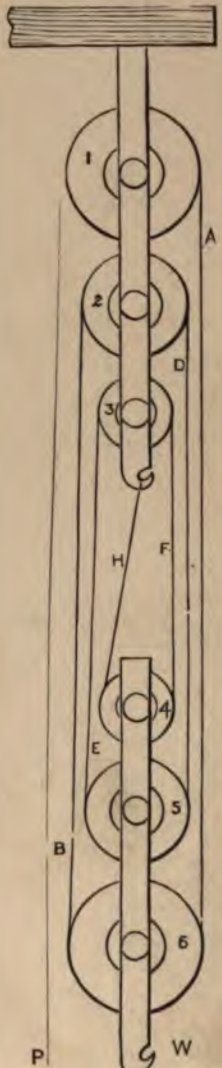


FIG. 1,221.

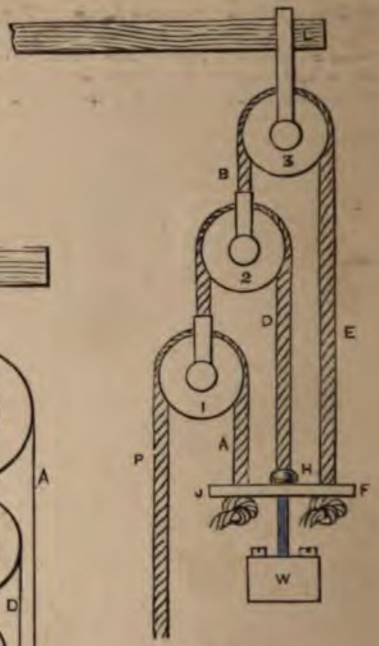


FIG. 1,220.

Second System of Pulleys.

In the second order of pulleys it may be seen that the fall is of one continuous length throughout, as at Fig. 1,211; but in order to show the action better, I have introduced Fig. 1,221 (which is just the same in action as Fig. 1,211). One end of the fall is spliced on the eyelet of the fixed block, instead of the runner, as at Fig. 1,211. It then passes round each pulley in fixed and runner blocks, as at 1 to 6, Fig. 1,221. Now look and see how many folds you have of the same fall. You see there are six. The cord is different to that at Fig. 1,219. This latter is unequally strained; Fig. 1,221 is equal throughout, and each part therefore sustains equal weight to that of P, and one-sixth of the weight, W. But take away the pulley 6, then you have this weight divided amongst the four folds. But add another pulley, making four in the runner block, and the weight is dispersed on eight folds of the fall, giving the mechanical advantage of eight. Therefore, we see that the advantage gained by the extra pulley in the runner is always twice as great as the number of pulleys in the movable block or runner. It should be noticed that if the extremity of the fall, H, be fixed to the lower block or runner, it will sustain half as

much as a pulley. Consequently, the rule will be as twice the number of pulleys, adding unity, is to one, so is the weight to the power. Hence the reason for rigging up Fig. 1,211 as shown. These blocks can be had from one pulley upwards. Do not forget that in all blocks there is a loss of power by the friction of the ropes, &c. For this add one quarter.

Blocks, Fittings, and Ropes.

EXPLANATION.

A block is measured by its length and should be three times the size of the rope which is rove through it.

SWALLOW.—The part through which the rope reeves.

FIDDLE-BLOCK.—A long block with one sheave above and larger than the other as shown at Fig. 1,211, and is used instead of a double block in situations where double, treble, or quadruple blocks cannot well be used for want of room, and are used with great advantage in close places, as in underground tanks having small manholes, also on a yard, or boom of a ship.

WHITE PULLEYS.—These blocks are made to answer double or treble pulleys. It is one pulley with two or more grooves of different diameters for the rope to run over or under, but nothing is saved by their use, except the little metal, which cannot be taken into consideration, if you think that these grooves must be smaller from one downwards, which gives extra friction at each diminution.

THE CRAB, OR WINDLASS.

Introduction.

Every plumber should know how to work the crab for hoisting. But how many plumbers are there out of fifty who can properly rig one, and how many are there in fifty able to tell the power of same under different circumstances? Town plumbers require the crab for hoisting their sheet lead, country plumbers for hoisting lead, and also for pump work; in fact, the plumber's own life is often depending upon this mechanical power, which, in a simple form, is known to the plumber as the "windlass" and in mechanics as the "wheel and axle," see "winch and axle," &c.

The Windlass.

Fig. 815 is the windlass, rigged up and ready for entering a deep well. The principle of the windlass is a continuous lever and very simple, but through the want of proper and accurate knowledge of such principle, hundreds of plumbers have lost their lives. I am not about to re-describe well-work here, but as this is the simplest kind of windlass, I take the advantage of it to lead you up to the crab.

Let the wheel be 8ft. in diameter and the drum or axis be 1ft. (general size 5in.) then 1 lb. on the fall A, will balance 8lbs. on the drum or on the saddle, and a small additional force at A, will turn the wheel with its axis or drum; but, remember, that for every foot the saddle rises the power at A, will fall 8ft. Now, instead of pulling away at this wheel, suppose we work the winch the general size of which is 1ft. 6in. to 1ft. 8in long at B, D. The power will be the same if the wheel and winch are of the same radius, so that you see this is nothing more or less than a perpetual lever, of which the fulcrum is the centre of the axis or drum, and the long and short arms are the diameter of the wheel and the diameter of the axis.

This being the fact, it is evident that the larger the wheel and the smaller the axis the stronger power will be obtained, and the weight will rise in proportion. But there is something far more important than anything which has yet been said, in which has been the cause of many a poor man's death in wells. It is when one man thinks, and often knows, that he can wind another up; and finds that at first he can do it easily; but, by-and-bye, the first roll of rope is round the drum, the man is losing his strength, the weight, in fact, is still increasing. He winds away, however, but when another roll is on the drum, he stops and cannot recover himself, and the other back to the bottom.

Then in considering the theory of the wheel and axle, measure the diameter of the middle of the outside rope to obtain the diameter of the axis, and proceed as before. You see that it is very easy to calculate the required power. Then do it before you go into the kind of work.

Crab or Compound Wheel and Axle Power.

You understand the preceding, and now you can easily understand the crab, either in single, double, or treble gear. Turn to Fig. 1,222. A, is the drum; B, J, the standards, which should be fixed down on a good foundation, and at P, P; L, is the large cogwheel (called a "follower" to D, or E, or L, can become a leader off the drum A), having, as the word implies, teeth on the outer surface. Each of these teeth should be counted. W is an axle, on this is another but smaller cogwheel D, the cogs of which are called "leaves;" the axle itself is, in this case, called a "pinion" (all this will be wanted in pump work). Now, all these leaves successively pass between the cogs of the large wheel, and are perfectly equal and similar to them. Hence the circumference of the wheel and pinions are proportional to their respective numbers of cogs and leaves. Say the number of cogs of the large wheel L, is 60, and the leaves on pinion D, 5, then the pinion will go round 12 times to the large wheel and axle once, because if you divide 60 by 5, you get 12 for the quotient.

Then if you have any number of wheels acting on so many pinions, and divide the product of the cogs in the wheels by those of the leaves of the pinions, the quotient will give the number of turns of the last pinion in one turn of the first wheel.

You may better understand this by an example. The number of cogs now in L is 100, and the leaves in E, 10; the cogs in H, 100, leaves in F 10.

Here you have—

L, with 100 cogs.
E, „ 10 leaves.

Power gained in 10 times. Then you have—

H, with 100 cogs.
T, „ 10 leaves.

Power again is ten times; therefore 10lbs. on F, gives 100 on E, and ten times this on L, because L, has ten times the quantity of cogs, so that it is $10 \times 10 = 100$, and 10 lbs. $\times$ 100 = 1,000 lbs. Then, if you require additional power, take the tackle, Fig. 1,211, make the standing block, L, good to the jib; let the end of the fall, P, go through the snatch, Fig. 1,214, this is made good to the bottom of a

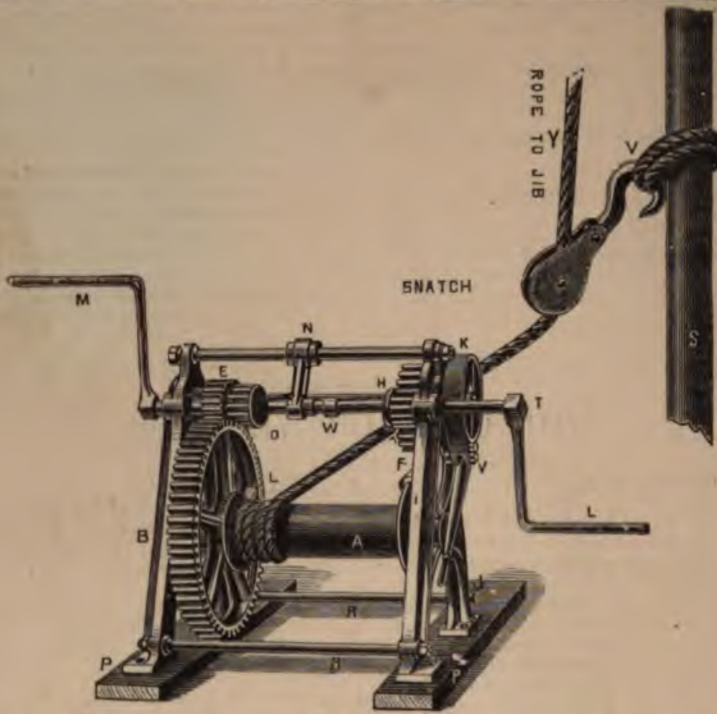


FIG. 1,222.

scaffold pole, &c., as that at V, Fig. 1,222, in order to get a horizontal line from the crab, and a perpendicular from bottom to jib. In this way you can raise a sheet of lead as easy as you like. The sheet should have the fall, or a chain run through it, then brought to the centre as at Fig. 1,223. Also have a guy fall or stay-rope fastened on at B, to steady

FIG. 1,223.

the sheet, to keep it from twisting round, or to pull it from one place to another. N.B.—Always see that the working parts are well oiled with *non-drying* oil, and the logs well greased with tallow and oil, or other good non-drying material.

Differential Pulleys.

There are other kinds of pulleys known as Weston's pulleys.

1 is the differential self-suspending pulley

on's pulleys, but which are made by many

They are very useful for lifting a sheet

length of chain required is somewhat against them for high lifts, you wanting four times the length of chain of the lift.

FIG. 1,224.

ROOF WORK.—IRON WORK.

Before we proceed with the lead laying, let us learn something about iron guttering.

Some plumbers scorn the idea of fixing a bit of iron work in their own trade, and often have to play when they might have been well employed; but, for willing workmen, I here give the simplest form of the work, which, if nothing more, will be useful knowledge.

IRON GUTTERING AND FITTINGS.

Measurements.

When ordering guttering to fit the angles of different buildings, it will be found much the best method to give a plan of the roof, especially if the gutters are to be of an ornamental character. For straight lengths, however, such as for a square-cornered house, the exact measurement will answer.

Guttering for Bay Windows.

In taking the length and angles, proceed as follows: Measure from A, Fig. 1,228, to the right angle C, and from C, to D, from D, to F, from F, to G. Here you have one internal right angle, as at A, one external right angle at C, these are connected by the short length of gutter I. At D, is an external obtuse angle connected with the gutter J; at F, we have an internal obtuse angle, also connected by a short length of gutter E.

Here we have two right angles and two obtuse, D, F. If the work will run, as in illustration, there will be comparatively no cutting, for the two right angles and the obtuse angles connect one into the other, a point worthy of consideration with bay windows, &c. When ordering guttering for such a piece of work as that shown, the following will be required: one internal right angle, A,

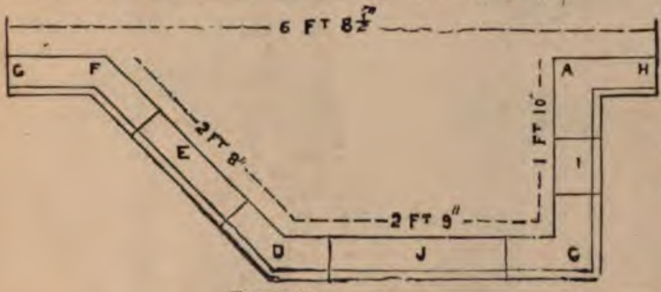


FIG. 1,228.

one external right angle, C, one short piece, I, (give the length), one external obtuse angle, D, (here give the required angle, for which, *see* Geometry), one short length, J, length — ft. — in.; one internal obtuse angle F, (give angle), one short length E, and so on. There will also be required six small bolts and nuts, besides those needed at the two ends. These are known as "gutter screws," also some stout screws for fixing the gutter to the fascia. These are the only points to be regarded in ordering for such places, excepting that a proper length of guttering is 6ft.; short lengths are frequently to be had. Of course, ing, order paint and red-lead putty.

Names of Iron Guttering.

The names of the different sorts of guttering and fittings are of some importance, as a wrong description is often the cause of much delay.

Half-round Guttering.

This may be seen at C, Fig. 1,229. This kind of guttering is of the plainest design. C, the socket end,

FIG. 1,229.

having a $\frac{3}{8}$in. hole in the bottom for receiving the gutter screw. This guttering is usually kept in the following sizes: 3in., 3½in., 4in., 4½in., 5in, 6in., 7in. and 8in.

Angle Pieces.

B, Fig. 1,229, is the angle which may be used for an external or an internal; but it is necessary to be careful not to work this, so that the socket will be on the wrong end. It will work in many places; but when it will not, an external and internal angle piece can be used.

The external has the socket on the reverse end to the internal, as shown at B, T.

Flashed Angles.

B, B, Fig. 1,229, shows an angle piece with flashing on the edge. This prevents the rush of water at the corner from overflowing the gutter. D, is the T piece or junction; E, is the nozzle piece, outlet, or socket; H, the faucet or stop end for fixing outside; H, T, the spigot, or internal stop end. These stop ends may be cut out of a piece of wood when the plumber cannot obtain a proper end. When fixing these wood ends they should be well painted all over, and should be bedded in solid red lead putty. After this, they should be fixed by sending a good wooden screw through the gutter bolt hole into the heading. It should be remembered that iron or sheet lead ends are the right thing to use.

Clips.

F, is the union clip. This is used to join two lengths together without having a socket in the end. It is also

FIG. 1,230.

handy when using an external angle for places where an internal should be used. Of course, by the use of this clip, short lengths without sockets may be worked in.

Brackets.

These may be made to any shape to suit the guttering, as shown at D, A, Fig. 1,230.

This bracket is constructed for screwing to the rafter or

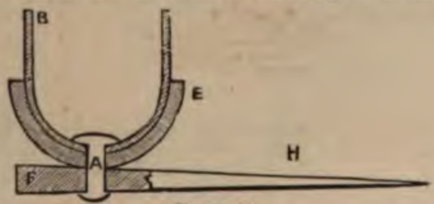


FIG. 1,231.

other place. The gutter lays in at D. The F, bracket is for O.G. guttering. Brackets are made to fix upon the wall plates, &c.

used for zinc guttering it should be soldered; E, is a piece 1in. wide iron hoop, having a rivet A, to hold zinc, hoop iron, and spike together. In some shops the plumber makes these brackets to fill up odd time. He simply gets the iron stem or spike F, H, pointed, and hole punched, then he gets the hoop iron the length required, also the zinc, and punches the holes, and then with a rivet, rivets the iron and zinc on the stem.

Fig. 1,232 is various kinds of gutter fittings, to be had from any lead merchants, and known by these names:—

O, cast iron O.G. angle external; N, cast iron O.G. angle internal; P, cast iron, with lion head O.G., without socket; O, T, cast iron, with lion head O.G., without socket; L, stop end, left hand, O.G.; L, T, stop end, right hand, O.G.; R, union clip, O.G.; Q, union lion head clip, O.G.; S, internal angle with socket; V, external angle with socket; U, O.G. cast iron outlet, socket or nozzle.

Of course, brackets are made to any shape to suit the work.

O.G. Guttering.

I, Fig. 1,233, is a plain length of O.G. guttering without a socket. This kind of guttering is generally used for places requiring much cutting, as by cutting up a length the other part may be worked in without trouble, having the clips R, Fig. 1,232, to connect the ends. K, Fig. 1,233, is a plain length of O.G. guttering, with clip in left hand. L, Fig. 1,233, is a plain length, with lion head and clip. Of course, iron guttering can be cast to any pattern or size to order. There are hundreds of different kinds kept in stock at the various makers.

Having noticed the fittings shown at Fig. 1,229, there is but little to describe, excepting that in O.G. work we have left and right handed, and left handed fittings are used.

At A, Fig. 1,234, is shown an external O.G. angle, having a flat bottom, with "set back spigot" end G. This allows the line of gutter to be flush, and to have the

FIG. 1,232.

Fig. 1,231 is a driving bracket for half-round iron or zinc gutters, B, D, is the zinc clip which turns over the edges of the gutter, and thus keeps it steady. Of course, when

appearance of a cornice. (This is an obtuse angle, generally cast to an angle, suitable for such places as at D, Fig. 1,228.) At B, E, I, Fig. 1,235, may be seen an internal

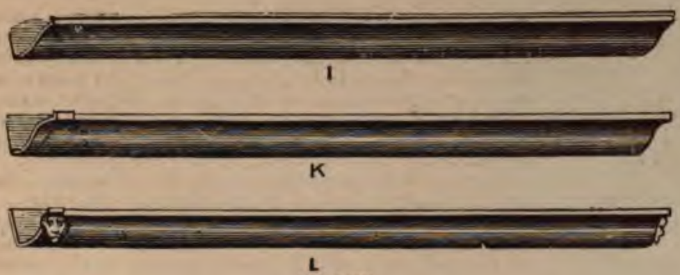


FIG. 1,233.

right-angled angle. B, I, C, Fig. 1,236, is a nozzle cast on the back to go into a trough gutter through roof, &c.;

FIG. 1,234.

FIG. 1,235.

FIG. 1,236.

FIG. 1,237.

and F, D, H, Fig. 1,237, a nozzle cast in the internal angle to come into a pipe fixed out of sight under the soffit of the cornice.

Drilling Cramp and Brace.

For drilling the holes in the ends of the gutters a proper cramp and brace will be required. B, Fig. 1,238 is the brace; S, the standard of the cramp, which you can screw

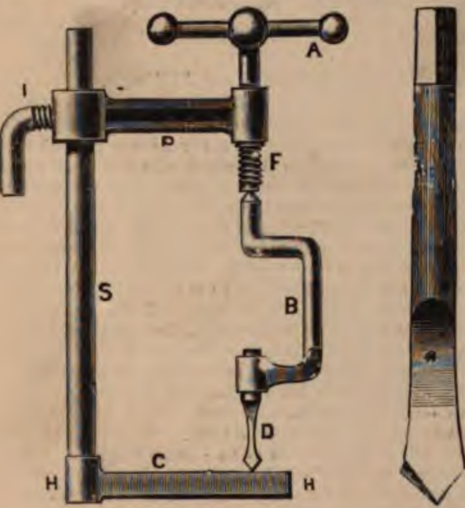


FIG. 1,238.

in your vice; P, the arm, which may be shifted up or down the standard; F, the tightening screw; D, the drill; ...ot. When working this tool the gutter should be between the drill and the foot, and the tightening screw F, screwed down (*not too hard*) and the brace turned in the ordinary way. Of course, the drill must be of the right shape, as shown in the diagram. This any smith can make.

Drilling Machines.


FIG. 1,239.

This, Fig. 1,239, is a drilling machine made by Messrs. Howel & Ward, with movable arm.

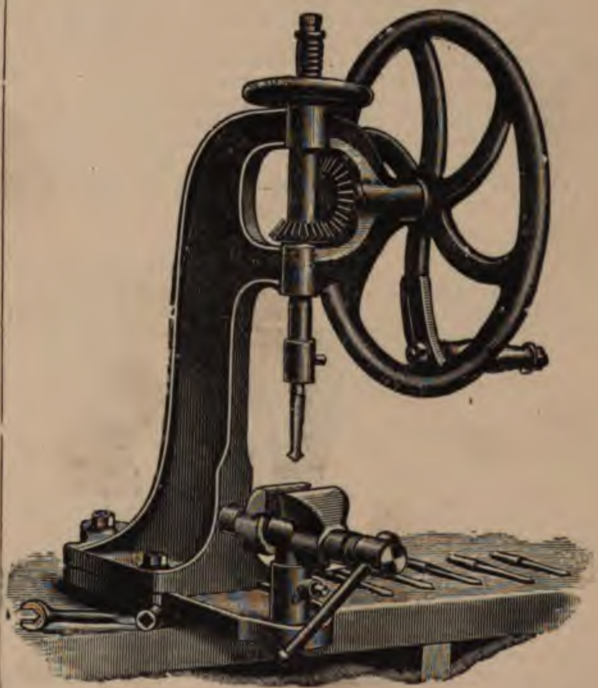


FIG. 1,240.

Fig. 1,240 is the better class of drilling machine, with vice for holding the work, but with fixed arm.

Fixing Iron Guttering.

The first thing required in fixing gutters is the fall. For instance, let us examine Fig. 1,241, which, for example sake, we will call the top of a greenhouse which requires to be provided with a gutter. In this it will be seen that the frame is level, and if a gutter is fixed true to it that gutter must also be level. Some people like iron gutters fixed to hold a little water to prevent the hot sun expanding the guttering. But instead of fixing the gutter to

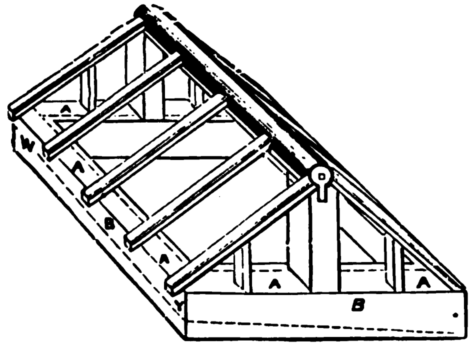


Fig. 1,241.

this, the workman should endeavour to have it fall one end to the other, just enough for the water to drain away and clean the gutter itself; if there is too much fall the guttering will be too far away from the slates, glass, &c., and the water will tend to run over at the angles, hence the reason for having the flushed angles, as described at G, B, B, Fig. 1,229.

Say the length from Y, to W, Fig. 1,241, is 24ft. Here three whole lengths of guttering can be used, and a 4ft. piece, with the two return external angles will about make up the length. In this case the plumber may (if there is to be no return angle at W) have, at least, 6in. to fall, as shown by the dotted lines. This would, however, be too much if the gutter had to return round the corner W,

Iron Heads.

(For these see Ironmongers' Price Lists.)

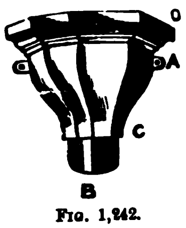


Fig. 1,242.

so that at this point W, a head, as shown at Fig. 1,242, will be required, or else a nozzle or outlet, such as is shown at E, Fig. 1,229.

Having settled upon what fall should be given, strike a [illegible] line W, Y, Fig. 1,241. Then fix the bracket, [illegible] half round work, or if for O.G. the first [illegible]wed up with ordinary wood screws, [illegible]tlet. For good work, however, the [illegible]hould be elongated to allow for the [illegible]tion of the guttering. This prevents the joints from leaking. The ends of the lengths should then be painted. Then with some good stiff and white lead putty as a bedding, partially bed the ends together, then with a suitable tool, a scriber, or even the point of a pair of compasses push one of its points through the hole in the bottom length, and also the hole in the top length, and work the tool about in order that the two holes may be brought true with each other, so that the gutter bolt (a ¼in., or $\frac{5}{16}$in. bolt and nut) may easily be put through the two holes to screw the two lengths together with a pair of pliers, Fig. 1,259, or otherwise. After screwing the next length slightly to that already in position, this other length can be fixed, and so on. After this second length is in its place the gutter screw should be tightened. See that the joint is sound, which is best ascertained by noticing whether the lead is pressed out at all parts of the joints, after which, clear off the surplus lead, and the joint is completed ready for painting two or three coats.

Cutting Iron Guttering.

For this purpose a good file, either taper or three-cornered bastard cut, and say 16in. long, independent of its handle, is required. The workman should mark the length to be cut, allowing for the socket, and place the gutter firmly upon the bench, the labourer holding it there, or if he is careful, he may work it in the vice between two pieces of sheet lead called "clambs" or "clamps." He then proceeds to cut the gutter by pushing the file over the work, taking care not to press too hard on the file. When it is brought back no pressure at all should be placed upon it, otherwise the cut of the file will be spoilt by breaking off the teeth. When a deep notch has been filed all round the gutter it should be struck smartly at the filed place upon a piece of soft wood, and the gutter will come asunder if it has been cut deep enough, or one end can be struck on the ground, and the gutter thus broken at the place filed. Should the iron be very hard, so that the file will not touch it, it is best to discard it for another or softer length, or on a pinch, it may be softened by passing it through a blacksmith's forge red hot, care being taken not to melt it; let it cool in sawdust or ashes, to cool slowly.

Iron Pipes and Fittings.

Having the guttering fixed, the next job is to fix the down or rain-water pipe. Of these there is a great variety, but that most common is the round, which we will examine. A, Fig. 1,243, are the ears or lugs; also the socket end. The pipe is simply slipped over the end of the spigot B of the head, Fig. 1,242, or over the end of the nozzle piece, E, Fig. 1,229, and with a 3in. rain-water pipe nail or spike fix the pipe firmly to the wall. Care should be taken that the nails have proper hold, and yet are not driven too hard, so as to break off the ears or lugs. If the brickwork will not hold the nails the joints should be plugged with wood plugs driven tightly between the joints (see fixing rain-water pipes). Suppose one or two lengths are fixed, and it is required to come off to another course, say at right angles or horizontally. In that case a bend, such as is shown at Fig. 1,244, must be used. On the other hand, if it is necessary to come off at an obtuse angle, a bend, such as is shown at Fig. 1,245, will be needed. On examining these bends it will be noticed that they have no ears; this is because they are often wanted for fixing at all sorts of angles to the wall. Sometimes with the heel at the back or against the brickwork, and sometimes one side, then the other, so that the ears should be cast on accordingly. Fig. 1,245 is the bend, having a cleansing hole at the back at D.

ve a
vith,
,246.
very

FIG. 1,243.

FIG. 1,247.

Set-Offs, Square.

Fig. 1,248, shows a square set-off, suitable for bringing a line of pipes from a line of brickwork, over a plinth or set-off in brickwork.

FIG. 1,248

FIG. 1,249.

Swan Necks or Bends.

as shown at Fig. 1,249, are often used to connect which project beyond the walls of the building, such as the gutters fixed on a projecting cornice. The swan necks or set-offs, are also used to alter the line of pipe, and should be of the proper length to bring the piping in a direct vertical line one with the other. The method of measurement is shown by the 4½in. between the arrows. Should the set-off be a trifle too long, it may be worked in by twisting the line of pipe a little on one side, which will not be noticed when connecting the gutters with the pipe under a cornice.

Loose Socket.

Fig. 1.246 also shows the loose socket for joining two pieces of pipe together; they may be had with ears. Iron clips or bands can be had with these sockets; also with the elbows, bends and set-offs. The pipes are sometimes fixed on blocks or iron thimbles, which will allow the pipe to stand an inch or so from the wall, so that the painter can get his brush behind.

Branches or Junctions.

These branches are for receiving one or more pipes, such as a rain-water pipe from off a bay window, &c., into the main pipe. Fig. 1,250 shows a branch piece with

FIG. 1,250.

FIG. 1,251.

two faucets, A, B, B being at an easy angle; Fig. 1,251 is the same thing at right angles.

The old easy bend composite junction. This is a cheaply made substitute for a leaden junction; there are various methods of getting over this. One is by

FIG. 1,252.

soldering the leaden arm E, Fig. 1,252, to the socket A, and makes much the best job. Having tinned

the socket half way down, splash (with plumbers' coarse solder) the space between socket and lead full of solder, and a first rate joint is the result.

Other times the branch E, is cast into the socket A, in one solid piece. I have a set of moulds for this purpose, but cannot recommend such work, as, to say the least, it savours with tinkers' work, and therefore I do not recommend it. I have various other iron and leaden joints (also unions). Fig. 1,253 is the elevation of the above.

FIG. 1,253.

Fig. 1,254 shows a branch having a long branch pipe and square trunk with door A, for clearing out. The door A, can be had in front or side. B, is at times made with

FIG. 1,254.

lead. Both the above are used for workhouse and prison work, also for poor property. F, shows enlarged view of the lead socket B, or it may be had to sizes marked thereon.

Shoes.

These are the last of the rain-water fittings, except when the pipes run into iron traps. The shoes are shown at Fig. 1,255. They are for the termination of the rain-water pipes delivering over gully traps, &c.

FIG. 1,255.

Traps, Iron.

These traps I do not recommend, as the earthenware is much the best, unless for places where the bottom is likely to get punched out. Fig 1,256 on the left is the ordinary

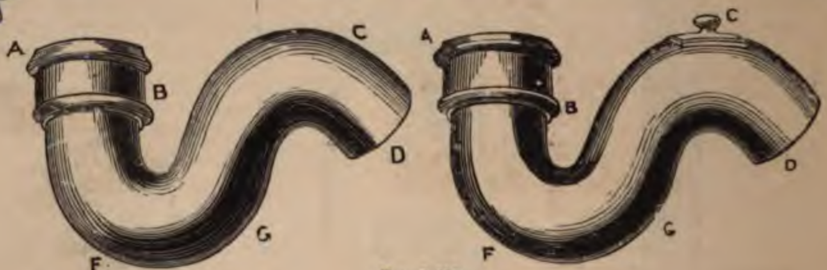


FIG. 1,256.

plain iron trap, which should never be less in thickness than ⅜inch. That on the right has a cleansing cap C, which is attached by a socket, cap and screw, bolts or otherwise. Fig. 1,257 is the trap, branch, and trunk, cast

FIG. 1,257.

in one piece. This may be had with cleansing cap and screws at A. Of course, the traps may be of any class; but I do not like iron, as they rust and get dirty, even though they are enamelled (as is sometimes the case). They are also made in parts with screwed and other joints, also with spigot and flanges.

Fixing Rain Water (or as it is sometimes called Stack) Pipes.

Many fix the pipe from the top downwards. This is not a bad plan in some cases—that is to say, where the line of pipe is unbroken from top to bottom; for there the plumber can thread a length of sash line through the whole of the pipes to hold up the bottom length whilst it is being fixed. Or in some cases the sash cord can be worked through a set-off. Another advantage is that one pipe does not so often rest upon another, but leaves room for expans[illegible]ather, it also gives the plumber a chanc[illegible]ne way or another for getting the

nail into the joints of the brickwork which at times is of great importance. The other style of fixing is to begin at the bottom and work upwards; here one piece supports the other whilst it is being fixed, but should the guttering be fixed and deliver direct into the nozzle piece into the pipe, care will be required in cutting this length, so that it can be fixed, even then the pipe cannot be properly socketed, it will only enter half its usual length.

Cutting Iron Rain-water Pipes.

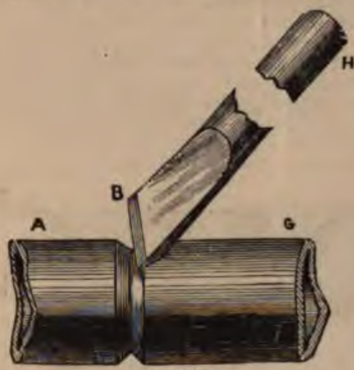


FIG. 1,258.

The instructions cannot be considered complete without a description of cutting iron rain-water pipe. In order to effect this, a deep notch should be filed all round the pipe quite true, as shown at B, Fig. 1,258.

The pipe should then be laid on something soft, such as earth, clay, &c., just where it is required to break. Should the pipe be very hard, this hard part or side should be placed on the top. The workman then takes a sharp iron chisel, H, and holds it in the position shown, and with a hammer strikes it a few light blows just to disturb the molecules, and in the direction indicated, and finally a sharp smack will cause it to drop off. By holding the chisel at an angle, the pipe, so to speak, rips itself off.

Driving Nails.

These should be driven in just to hold up the pipe, then with a punch made with a short length of iron pipe, say ¼in. or ⅜in., they should be driven home. The pipe should be held up while this is being done, as there is then less danger of breaking off the ear.

FIG. 1,259.

These pliers (Fig. 1,259) are used for screwing up the gutter bolts, nuts or screws, as previously spoken of under the heading Fixing Iron Gutters.

LEAD LAYING.

Guttering

Having gone through the simple part of gutter work, viz., that appertaining to iron gutters, I will now commence the more important work belonging to the plumber, namely LEAD LAYING, an art which very few plumbers ever thoroughly master, for the simple reason that it is too often done by rule of thumb, and without sufficient care or labour. I, therefore, particularly ask you to follow the instructions here laid down, because I have worked in almost every conceivable manner, and after taking every thing into consideration, I am now of opinion that the following rules properly carried into practice will be found the best and most suitable for general work.

I shall begin by going minutely into the elementary part, and continue step by step until we have arrived at the climax of roof work plumbing. There is a marked difference between cast lead and milled, the former requires to be worked with rounded corners and greater care as it is easy to rip or break, whilst the latter is more tough and may be worked with sharper tools.

Gutters, Drips, and Falls.

The first thing required is that the woodwork be done evenly and true, with proper falls, drips, &c. Drips should not be less than 1½in., but as much more as you can get. Throughout the job all boards should run the way the water is to run, with at least 1in. to 1½in. fall in 10ft. lengths, or as much more as you can get, with the nails properly punched in. The plumber should instruct the carpenter, about all drips, falls, cess-pools, outgoes, socket pipes, springings, rolls, ridges, wedges, dot holes, curb-boards, templets, &c. In fact, on a good job the plumber should have a carpenter whenever wanted, as there will often be an infinite number of jobs for him to do, after he thinks all is ready for the plumbers, unless he happens to be a first-class plumber's man. If these little jobs are not attended to, and when required, the work cannot be expected to be all first-class, as, when the carpenter is refused, then the plumber often loses all interest in the job, which is the very worst thing that can happen for the work.

Hints for Measuring Lead Gutters.

This is a point in your work which will require your particular attention, for although it is a simple matter to measure a single gutter, it must not be lost sight of that this must be done correctly; for what is worse than a short gutter? And yet it is a very common thing to find men in large London shops, holding the position of foremen of plumbers who are *continually* in the habit of cutting the gutters too short or too long, very seldom the latter.

This unscrupulous kind of thing is continually being blundered, and often men have to stretch the lead for, s[illegible] 2in. in 10ft.; this is in order to make the lead co[illegible] instead of sweating, burning, or soldering a bi[illegible] speak of this knowing full well that it is pr[illegible] only in the small shops, but in the large on[illegible] disgrace not only to the men but to the fo[illegible] employers. Therefore I ask you to be at [illegible] particular in all your measurements, and if [illegible]

do all your work regularly, it will save you a great deal of trouble, and be the means of your work coming out at a fair and reasonable cost, which should be of great importance to the plumber.

We will imagine that we have a gutter whose length is 8ft. 10in. long, and 5in. turned up at the head, as at C, Fig. 1,267; it is, say, 2ft. 6in. wide at the head, and 2ft. 5in. at foot, D, D, and 10in. up the roof and over the springing, as at F, Fig. 1,266.

The drip we will say is 1½in., and the lead for the splash lap is to be 2in.; but remember that in stormy weather the rain is liable to beat back at the side wing (see L, Fig. 1,269), so that this should protrude past the drip about 6in., so that you will require another 2in. in all, say 6in. The head turn up is, say, 5in., in all 9ft. 9in.

You will have some "stuff" to spare, but this will be wanted for bale, tacks, &c., and being stout is just the thing for the job. These sizes should be always entered

I have shown at Fig. 38 and description, how to cut up sheet lead, and given hints as to the best method of handling the sheets.

The lead on large jobs is usually cut out on the job by the lead layer, and, if the job is by contract, is included in the work, when all cuttings are charged as so much lead worked—this is to compensate him for cutting it up; but if the lead is cut up by another person, then the whole is weighed on the job, and this constitutes the amount laid, which is to include the trimmings. All cesspools, "outgoes," sockets, pipes, and bends are extras, or usually paid for day work, unless otherwise stipulated.

Fig. 1,260 is the way to form a scaffold for unrolling the lead; it is wide and roomy.

Fig. 1,261 is a much too narrow scaffold, and is a nuisance to work upon. I shall still give you some more practice in gutter measuring, as this cannot be learned too well.

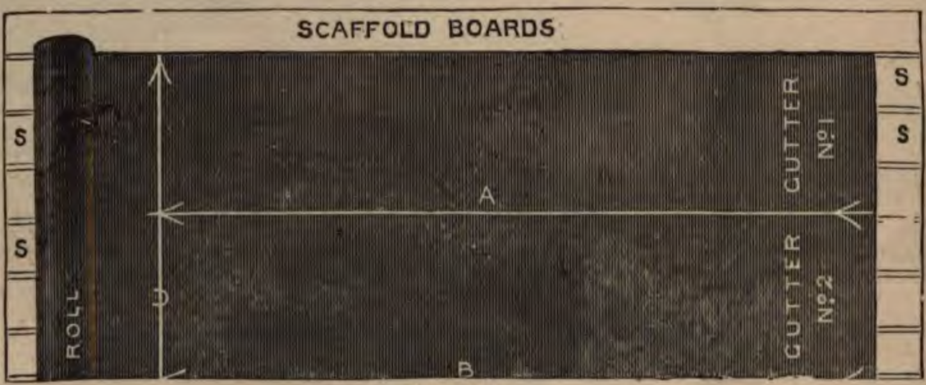


FIG. 1,260.

FIG. 1,261.

into the plumber's pocket-book, and numbered from 1 onwards. The situation of the building should be also booked, such as front gutters, side or back gutters, "flashings," hips, and ridges, dormers, &c., or north, east, south, or west wing, for reference; and to be sure that the lead also bears these marks just within the outer roll, or, if you can rely on its not being rubbed off, on the outsde.

Fig. 1,261A is the plumber's pocket knife, which should be kept nice and sharp, and with a good point. The

FIG. 1,261A.

plumber should also have a good strong two- or three-bladed knife, not too big, but one whose handle is about 4in. long, kept well sharpened, for washers, &c. Never ike a pocket knife with a hammer, it strains the rivet.

Gutter Measuring, again Illustrated.

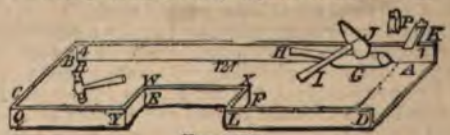


FIG. 1,262.

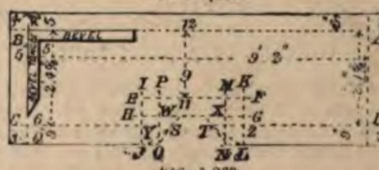


FIG. 1,263.

Suppose the gutter which you are about to lay to be one similar to that illustrated at Fig. 1,262, which is an

elevation, and let diagram No. 1,263 be a plan of the lead, and diagram No. 1,264 be the drip. Here you have three views of what you will have to do.

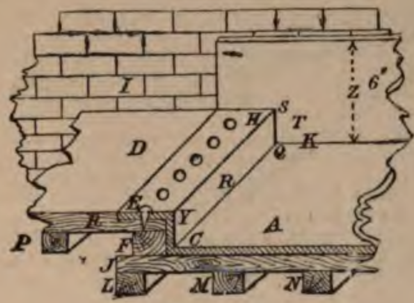


FIG. 1,264.

I shall now explain the method of taking the size, and entering it in your pocket book.

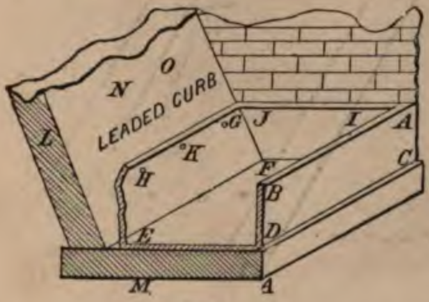


FIG. 1,265.

First take the height of the turn-up against the wall. We will say that the specification states it to be 6in. all round brickwork, as at Z, Fig. 1,264, and 9in. under the slates, as at H, E, G, Fig. 1,265, and at springing, Fig. 1,266. But sometimes your lead may be only 5in. at the head, as at R, Fig. 1,267; and if you have, say, 1½in.

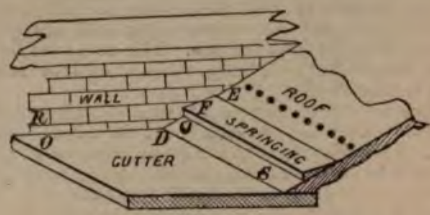


FIG. 1,266.

fall, then your lead may be 5in. at the head, and 6in. at the drip. This will allow you to put in a straight length of

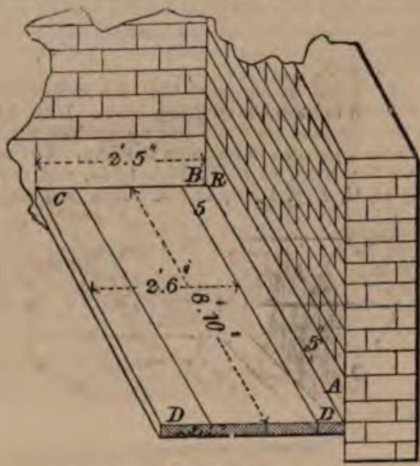


FIG. 1,267.

flashing, and the work will be all the better. Therefore, we will say that the turn-up shall be 5in. at the head, and

FIG. 1,267A.

FIG. 1,267A.

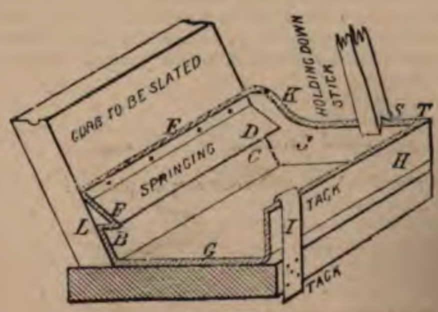


FIG. 1,268.

6in. at the drip. Now you require a rule, the one used by the plumber is, generally, a four-fold 2ft., but I like the steel rules, made by Chesterman, as with these pliable rules you can measure round a coil of pipe, or make a bevel, and do lots of good work with it. For this, see Fig. 1,267A. Or, instead of measuring with the rule, a tape can be used with advantage. The tape used by the plumber should be 66ft. long, which enables him to measure a whole coil of lead pipe at once.

Having an insight into your job, proceed to measure the width of the gutter at the head, Fig. 1,267 : here say it is 2ft. 5in. Next measure it at the drip ; here you will most likely find it to be considerably less, according to the pitch of the roof, and the fall of the gutter ; say that it is found to be only 2ft. 1½in. ; next measure for the other turn-up which may be to go up a slated roof with springing. If so, and the springing is nailed on, say 4in. up the roof, as at F, Fig. 1,266, then the lead should be cut to come up the springing, and if the pitch of the roof be easy, as there shown, it should go well up the roof, at least 5in. or 6in. past the sharp arris F ; but if the pitch of the roof be very sharp, as at E, Fig. 1,268, then from 3in. to 4in. will answer. It should be observed that the lead should go up high enough to keep out drifting snow. Now, having seen how far the lead should stand up against the walls and up the roof, proceed to examine the drip. Let us say that it is a 2in. drip, as at Y, Fig. 1,264, and that the splash lap G, C, Fig. 1,269, is 2in. This will make up

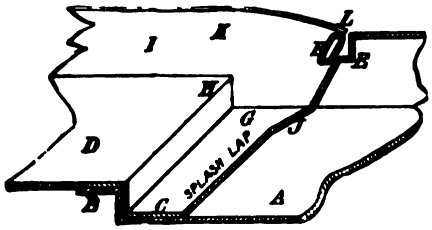


FIG. 1,269.

4in. I should here also recommend you to examine some of the larger diagrams, Figs. 1,310, 1,311, 1,312, &c., and consult yourself, as to whether or not, you could measure the amount of lead for any one of these particular figures, and you should find out which would be the first piece of lead to measure, or the last to put on.

Now proceed to cut out your lead for the gutters and "get it up" (this is a trade term signifying getting the lead on the roof, and for this see Mechanics for Plumbers), then I will instruct you in working it to its place.

I have on page 45, Vol. I., said sufficient to enable you to shift the heaviest of sheets necessary for roof work with the least amount of labour, and have there shown the method of making your scaffold, and unrolling your lead ; and I have, in Mechanics for Plumbers, said sufficient to enable you to hoist from a piece 56lbs. to a whole sheet, therefore we can now dispense with all this, and proceed at once to our lead laying.

Lead Laying—Gutters.

Having your lead up, and your proper piece of lead for the place (which should be found by its bearing its proper mark or number), clear a place for unrolling it ; if you cannot find a suitable place make a platform with some scaffold boards and putlogs, quartering, &c., or as best you can (for this see Fig. 1,260 which is wide enough for two gutters, whilst Fig. 1,261 is barely wide enough for one, and is very awkward to work upon, and the work cannot proceed in comfort). At any rate some place must be provided to roll out the "stuff." Having the lead

FIG. 1,270.

unrolled, with a dull dresser (Fig. 1,270), flatten or smooth it so that the surface is free from lumps, &c.

Be sure that you have the right piece of lead for the place. Next take your measurements as follows (see Fig. 1,267 at A), measure up to, say, within ½in. of the second

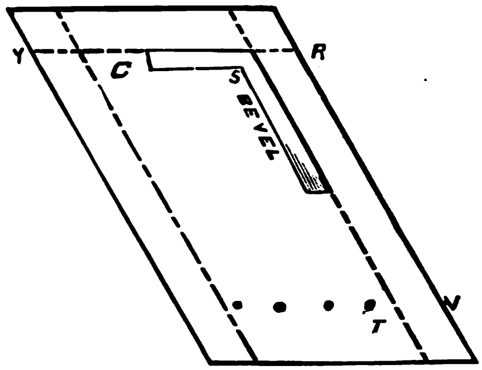


FIG. 1,271.

joint in the brickwork, as at E, E, Fig. 1,285, &c. ; this is, say, 5in. Set this upon your lead, as at V, R, Fig. 1,271 ; next measure the turn-up at the head of the gutter, as at R, Fig. 1,267 ; this is, say, 4½in. Now set this out upon your lead, as at R, Fig. 1,271, and snap a chalk line on these marks, as shown by the dotted lines. Next measure 4½in. for the end of the gutter, as at B, Fig. 1,267. Now take the bevel of your wall, as at C, B, R, A, Fig. 1,272,

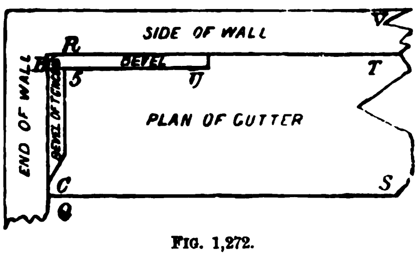


FIG. 1,272.

and lay this bevel upon your lead, as at bevel, Fig. 1,271, and then snap a line (Y, R) true to the tongue of the bevel. Now measure the width of the gutter, as at D, D, Fig. 1,267, and set this out upon your lead, less ⅜in. or so for allowing the lead to go into its place easily. Now measure the head of the gutter, as at R, C, and also lay this (*less the substance of the lead*) upon the lead, and snap a chalk line, as shown by the dotted lines, at C, D, Fig. 1,271. If the corners ar[illegible] up, you will save labour by cutting them o[illegible] B, Fig. 1,281.

Pulling up the Sides, &c.

For this job you must have a pulling-up stick. This is only a piece of quartering any size you can get, say 3in. by 4in., or something like that, and about 6ft. to 10ft. long. Place this just within the chalk lines, so as not to rub them

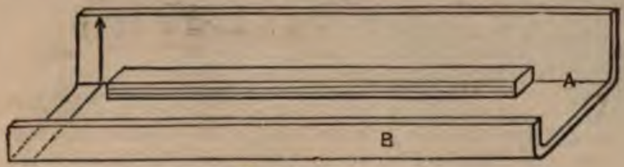


FIG. 1,273.

out (this is shown at A, Fig. 1,273) and kneel upon one end, your mate doing the same upon the other. Then let both catch hold of the side—say the side up roof—and pull it up, as shown. Also pull up the wall side as at B. If the lead

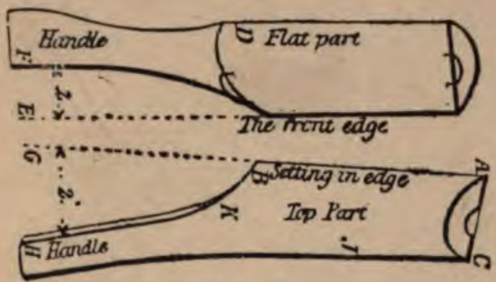


FIG. 1,274.

is very stout or the weather cold, it may not turn quite so easily as you would wish, but if it does not come pretty square push it back and pull it up again, and so on for a time or two until it is middling sharp. After this let your

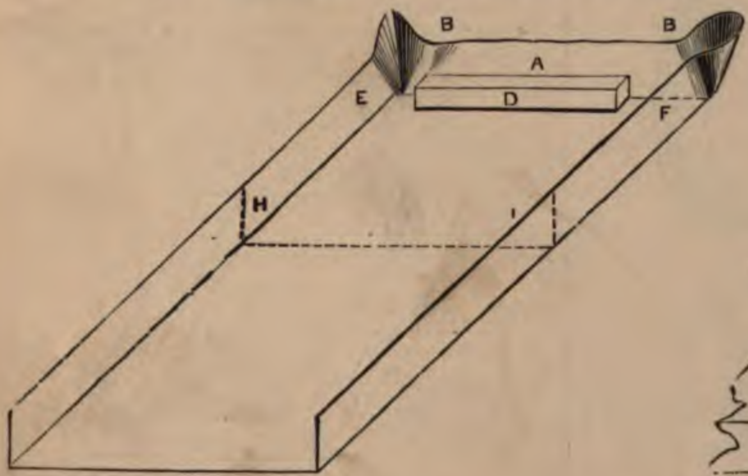


FIG. 1,276.

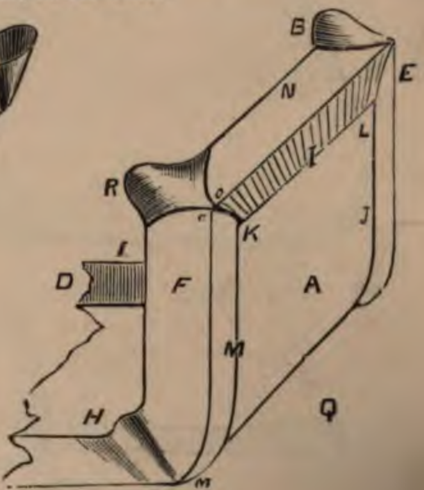


FIG. 1 277.

mate get a holding-down stick, made out of a piece of slating batten, say 3ft. long, having a notch cut in the one end to receive the stand-up side of the lead, as shown at A, Fig. 1,275, and S, Fig. 1,268. Next take the hornbeam dresser, not too sharp, Fig. 1,274, which is a plan and a side view, showing the handle of this dresser standing well away from the setting-in edge, so that you shall not knock your knuckles when at work—it will be all the better to touch same (touch is tallow candle rubbed on the edges). Then hold the edge, A, B, of the dresser on the chalk line, as at B, Fig. 1,275, and your mate holding down

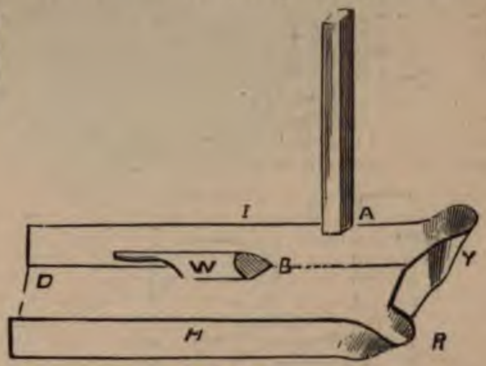


FIG. 1,275.

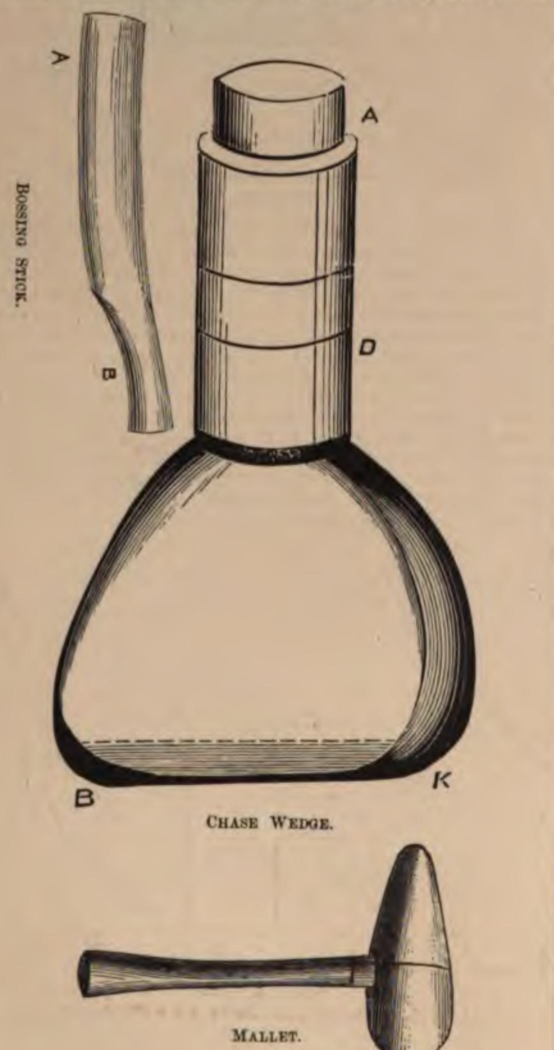
on the end with the holding-down stick, A, to prevent the lead rising; then with a good heavy hammer or mallet strike the dresser at W, so as to drive it into the angle, which is called setting in the lead; but do not drive it in such a manner as to knock holes through the lead; use the dullish dresser and go all the way along the line *until you are within that part which is to go over the drip, say about 6in. or so from the end.* This must be borne in mind: never set angles in square, which require to be afterwards worked down, for should you set this part in at all sharp, most likely you will find it to rip when you are working or bossing it down in the corners, &c., at all events it does not improve it, and prevention is better than cure. Nearly all sharp arrises are set in, in the manner shown at B, Fig. 1,275, viz., for roof work.

After you have set the arrises in with the dresser, b[illegible] the back of the arris in so as to square it up, this squa[illegible] the arris and also tends to thicken it in the angle, a[illegible] thus this part of the lead is improved accordingly. Suppose the lead to be now in the shape of that illustrated

at Fig. 1,273, and that you want it for the gutter, Fig. 1,276, it is evident that the head of the gutter must be pulled up (and should have been done before the setting). This is pulled up in much the same manner as were the sides, and is clearly shown at A, D, Fig. 1,276.

Having done this, next "break it up." This is done by placing your hands or your feet on the sides at H, I, Fig. 1,276, so as to thrust the sides out, then your mate catches hold of the two corners and lifts them up as at F, E, Fig. 1,277.

The mate now stands on the lead, and holds F, E up; you put the stiffening in, that is, take a dresser and the mallet, Fig. 1,278, and with the side arris of the dresser make the concave lines as at J, L, K, M, Fig. 1,277, and



BOSSING STICK.

CHASE WEDGE.

MALLET.

FIG. 1,278.

with the dullish chase wedge, Fig. 1,278 (also see Figs. 1,290 and 1,291), or with the end of the dresser, make the angle stiffener K, L, Fig. 1,277.

Bossing up Corners.

So far let us suppose all to be done, and ready for bossing, or working up the corners, which is done as follows:—First let the mate (plumber's labourer or assistant) hold the lead nice and steady from swaying about, this makes the work much easier for the plumber, and if the lead be firmly held, each blow with the bossing stick tells much better than it otherwise would. I like my labourer to kneel on the right knee in about the position of Q, Fig. 1,277, and to place his left knee at or about A, and with it press firmly against the lead, and with his hands hold the sides, F, E, by pulling it towards the knee, and in such a manner that it will not open outwards; this is one of the best methods of holding the lead steady whilst its corners are being bossed up. The plumbers' work is as follows:—Take a BOSSING STICK, see Fig. 1,278, which is nothing more than box, or other hard wooden tool, such as lignum vitæ, &c., and also the mallet, Fig. 1,278, and proceed in the manner shown at M, R, F, Fig. 1,279,

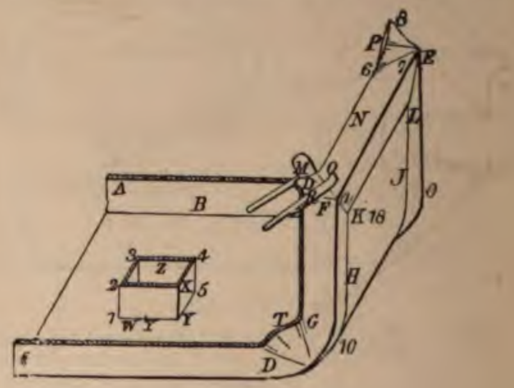


FIG. 1,279.

and work the corner up, keep it rounded, but at the same time keep the points *a*, true with the arris lines, so as to maintain a square line round E, F. This is done as

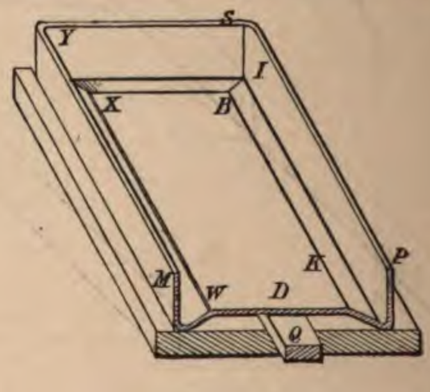


FIG. 1,280.

follows:—Place the mallet as at M, under the lead, and with the bossing stick work the lead from F, towards M, bri it all the surplus metal; keep working it

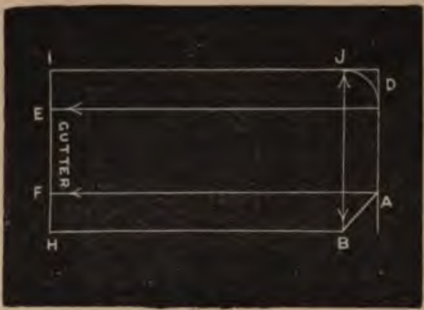


FIG. 1,281.

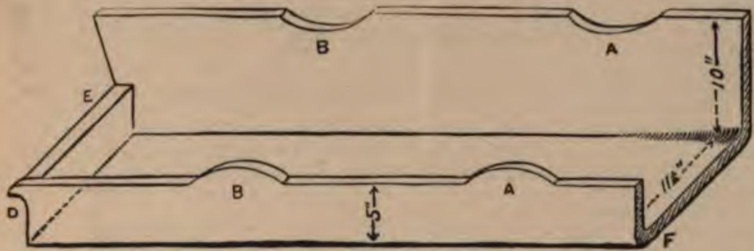


FIG. 1,282.

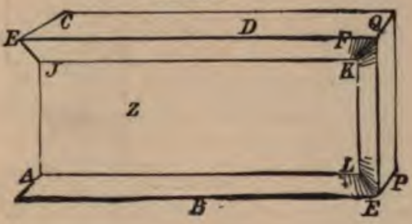


FIG. 1,283.

upwards very steadily but firmly, and do not attempt to work it square, or to a sharp arris, *keeping it rounded as at* B, R, Fig. 1,277, until it has been worked to its proper height.

When it is high enough you may cut off the surplus metal, and then square the corner up similarly to that shown at S, Y, Fig. 1,280. Another way: I, as a rule, cut the surplus lead off the corner before pulling it up; Fig. 1,281 at J, D, and A, B, illustrates what is meant. Of course, when the corner is worked up square, there will be a quantity of stuff to spare in the corner. To get over this difficulty, and to save your labour, before you start to boss up, take the knife, see Fig. 1,261A, and cut the corner as at A, B, Fig. 1,281, or, as some plumbers do, at D, called "rounding off" the corner. The corner is just as well off if the same has to be bossed right up; but for some drips (spray or blocked) or for rolls, leave the corners on, also for corners up the springing boards or up roofs, as shown at K, Fig. 1,268, &c.

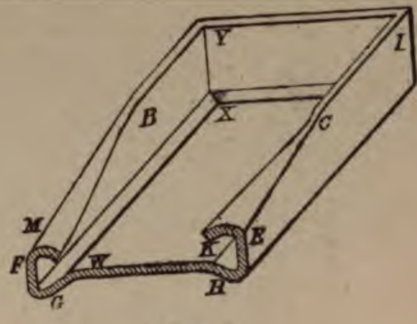


FIG. 1,284.

Now you have the corners to your fancy, put the gutter down again as at Fig. 1,282. This is done by the mate taking hold of both corners, and you at the sides at T, D, &c., Fig. 1,279, pull up the sides whilst he "bashes" it down, at the same time he follows it down with his hands to prevent it springing upwards, and thus rounding itself, that is, it is likely to rise up about 1½in. or so if not followed and firmly held down. This is important. Not one in twenty plumbers are alive to this. Next turn it on its side as at Fig. 1,283, and straighten up the sides with two dressers, and put the stiffeners straight as from J, K, and A, L; then turn it on its bottom and put the hand-holds in the sides by turning the edge over something like that shown at M, E, Fig. 1,284, but be careful to put them 2ft. or so from each end, or in such position that the lead will carry itself without bending. At A, B; A, B, Fig. 1,282, are shown the positions of these hand-holds—holds are shown, but this latter engraving at A, B, shows the piece cut out, by the carelessness of the engraver. The lead should

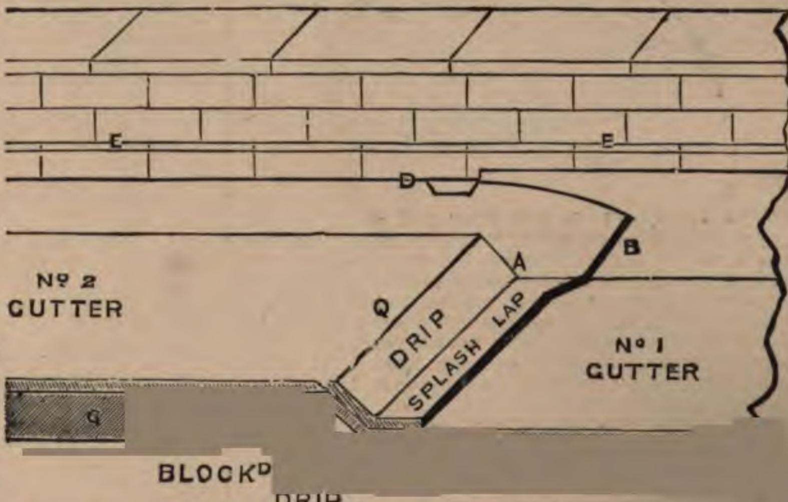


FIG. 1,285.

appear knocked over to form a kind of hand-hold ab 2in. or 3in. diameter. As before said, as shown at M, E, Fig. 1,284. You see that the head of the gutter

Fig. 1,282, is worked up square, for a square drip, and is turned down at E; this is for turning into the rebate P, Fig. 1,293, in the head of drip, where it is shown nailed down. I may here remark that sometimes, especially for deep corners, such as 9in. to 12in., that it will be at times less trouble to cut these corners, and wipe them up as will be shown and illustrated in lead cesspool making, Figs. 1,304, 1,305, 1,306 and 1,307; and at other times a dog-ear may be conveniently employed, especially where time is an object. The dog-earing is shown at Fig. 1,313, and will be explained further on. Next we will put the gutter into its place. First see that the joints of the brickwork are properly raked out to at least 1¼in. for the turn in part of the flashing, which should be the first joint above the top or turn up part of your lead, as shown at E, E, Fig. 1,285.

"Putting" the Gutter into its Place.

First of all sweep the boards free from grit, &c., see that the edges of the board are true one with the other, and the nails properly punched in. Some, like the late Mr. Joseph Davies, a well-known builder of Kensington, like the nail holes stopped with putty to prevent the galvanic action which is often set up between the iron and lead. The head of the gutter or the drip No. 2 gutter, must be rabbetted out as at P, Fig. 1,293. Then having all complete, lift the gutter into its place, and if a very large one, lay a piece of quartering up the centre of the gutter boards, for the lead to lie upon, as shown at Q, Fig. 1,286. This keeps the lead up in the middle, and allows the edges to take a bearing, and also causes the gutter lead to be narrow, thereby allowing it to move freely one way or the other. It also makes the gutter lie more solid during the fixing

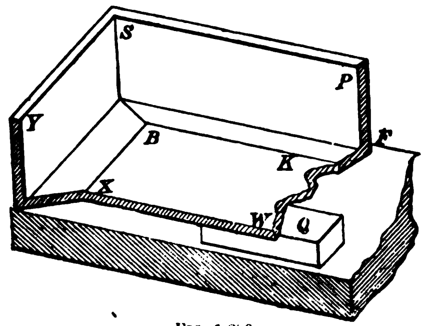


Fig. 1,286.

of the edges, and is well illustrated at F, and X, Fig. 1,286. When the quartering is withdrawn, of course the raised part can easily be knocked down, and the outside edges do not have that tendency to rise as they otherwise would have, especially if you can get a wall hook or nail into the brickwork, and through the top part of the side of the stand, or turn upside as at the dark spot at the corner end of the stand up lead, Fig. 1,264. But before you attempt to nail it down, see that the lead is well up against the end of the drip, as at C, Y, Fig. 1,264, also at P, Fig. 1,293. The head of the gutter should be well driven up by taking it about 5in. to 10in. down the gutter, and then driven up against the drip with force, keeping it well down on the gutter boards at the same time.

Now, having the gutter put properly into its place, begin to lay the head part, whether it be for a drip or otherwise, it requires proper attention in the fixing. First let the mate come forward with his holding-down stick, and whether it be for a drip or stand-up corner let him place the holding-stick as at S, Fig. 1,268. Now put the end of your dresser on the corner, as at T, Fig. 1,268, and whilst the mate bears heavily on, you, with a large hammer, strike the dresser on the back; this should ensure the angle being well down upon the gutter boards. You may now fix it with a wall hook or 4in. nail, or otherwise, to prevent it rising whilst working it down. After this, fix the other corner in a similar manner. Now you can with your hammer and dresser knock down the stiffening edges as shown at X, B, K, Fig. 1,286, &c., and then finish the other end, which for this purpose I will say is to discharge into a rain waterhead.

We have now come to gutter No. 2. Let the gutter No. 1, Fig. 1,293, be the gutter just laid, and No. 2 be the next gutter to be laid. In this gutter there is a drip to be worked down, which will require the particular attention of the uninitiated, but which, after due care, he will be able to work down with facility.

Working down Drips.

The gutters (Nos. 1 and 2, Fig. 1,293) being laid, excepting the working of the drip P, Q, N, let us proceed to do this. Refer to R, Q, G, Fig. 1,287.

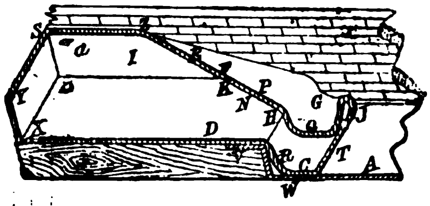


Fig. 1,287.

First see that there is no dirt below the top and bottom lead; especially look for bits of stone and such like. Now let your mate hold down the corner which you intend to work, as shown at W, Fig. 1,288, to keep it from springing

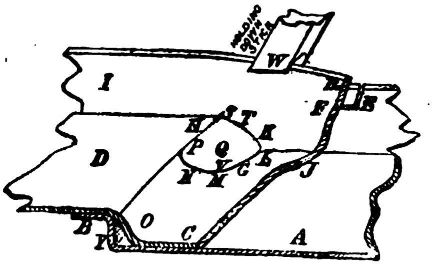


Fig. 1,288.

during the work; then with the side part of your mallet just knock the lead R, Fig. 1,287, down over the edge of the drip as there shown, but keep 4in. or 5in. away from the corners; you may then knock the lead pretty nearly home with a soft hornbeam dresser or dull chase wedge.

Chase Wedges.

For the first part of this drip work, use Figs. 1,278 and 1,290, &c. I like to make my own chase wedges, or "points" as they are sometimes called, out of oak, elm, or such-lik[illegible] [illegible]d finish with boxwood tools.

Now turn down the stand-up part of the lead, as shown at Z, E, P, Q, Fig. 1,287. The labourer now puts his stick on the lead at G; then you, with a dummy (this is a stick loaded with lead), Fig. 1,289. Begin at E, Fig. 1,287, and work the lead up from E, to F, and P; this will stretch the lead towards the drip and allow the lead in the corner of the drip at G, to be worked down with less strain than it would be if otherwise manipulated. Remember that you have to get sufficient lead to make up the deficiency between E, and G, Fig. 1,287.

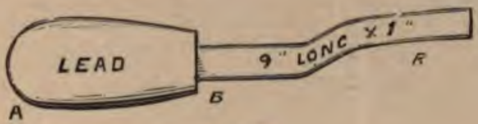


FIG. 1,289.

Now, having obtained as much lead from the stand-up side of the lead as required, finally turn it up to the wall and commence to work the corner as follows:—Take the "point," Fig. 1,290, and begin by working the lead all

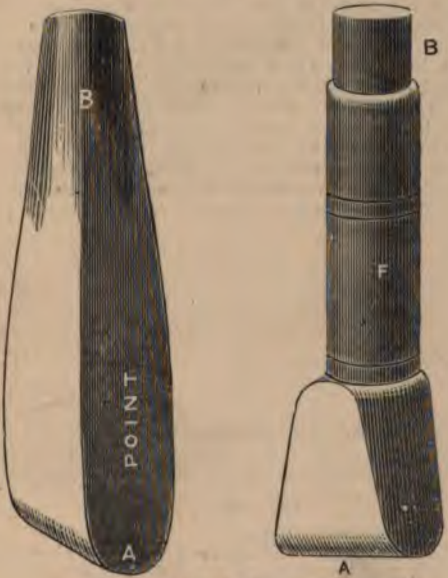


FIG. 1,290.

round, as at S, T, Q, N, &c., Fig. 1,288, into a kind of easy bulge, as shown at P, Q, to make up for the extra lead required to go back into the corner, care being taken not to strain or thin the lead more in one place than another. With care this lead is easily worked up, and is done partially with the small mallet and by holding the point at a suitable angle, and tapping it on its end with a small mallet so as to drive the molecules of lead the way you would have them to go. Keep working at this, shifting the point to a fresh position each time, blow, or tap, and in such a manner that you cannot strain the lead more in one place than another; proceed thus until the corner is worked back, which must be done in such a manner that it shall be thick lead at the extreme point and without a hole (called a "cock's eye"). A plumber making cock's eyes in drips is fined a half-gallon of ale in London for his bad work.

Some plumbers only use a small mallet for this job. I sometimes work one way and then another. Some plumbers fasten the overcloak lead, as at D, N, Fig. 1,293, before they finally work the corner in, then they get the mate to hold on to the edge of the lead at or about K, and in such a manner that the lead is being pushed home with the holding-down stick, which is a very good plan to adopt. Of course, the other corner is worked in a similar manner. At times, these drips are finished with very sharp angles, with such tools as at Fig. 1,291. Now, having the corners

FIG. 1,291.

worked home, and the ends of the gutters fastened down, as at N, Fig. 1,293, to keep it from rising, you may trim your edges round and about your drip, similarly to that shown at G, Fig. 1,269, and also at J, T, Fig. 1,292, but not in such a manner that the lead will be weakened.

Plate.

Some plumbers put a steel plate under the lead to be worked down; it allows the lead to move back with greater freedom and keeps the lead smooth. A piece of broken saw answers for this plate, and a little touch causes the lead to slip easily. The lead should be trimmed off, as shown by the dotted lines marked PROPERLY TRIMMED,

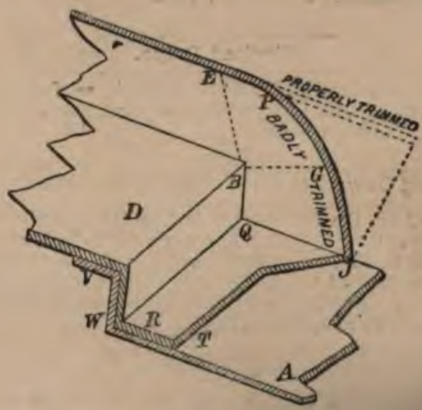


FIG 1,292.

Fig. 1,292, and not as shown from P, G, J edge, because if done as shown in the flashing cannot cover this stand-up edge unless the flashings are deeper than is othe

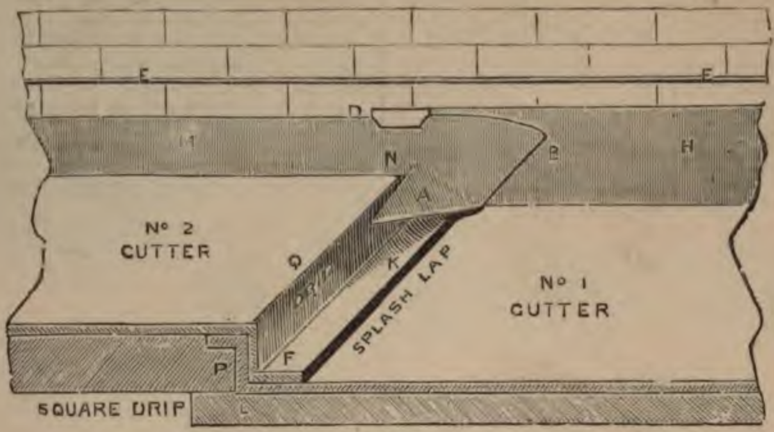


FIG. 1,293.

Next is the trimming; the splash lap Q, R, Fig. 1,292, which should be left to lay upon the bottom lead at least 1½in., and cut on the splay as shown at J, this lead answering two purposes: with shallow gutters it keeps the turn-down lead Q, R from coming away from the drip; and also prevents the rain from splashing up the drip which would otherwise be the case. Some plumbers have a very peculiar notion about this splash lap, and think it induces capillary action—this may be the case, but the capillary action is almost entirely checked at the angle; but if you cut this splash lap off and allow the lead to go, say, within ¼in. of the bottom of the drip, then the capillary action will rise at least 1in. if the lead stands close back to the back lead, and if the front lead should be some distance away, which is often caused by the temperature of the atmosphere, then the rain splashes up, and so the wet gets in. My experience is, that it is imperative to fix a splash lap to all drips under 2in. in depth. The duffer would, of course, plead no splash lap, as it is more trouble for him to work, in fact, he can't do it; but to my reader let me say, Don't let capillary nonsense interfere with proper work!

Blocked Drips.

Some plumbers block the drips out, as shown at L, Fig. 1,285. This is a good plan, and saves labour in working the drips home.

Tacking Down the Ends of the Overcloak Gutters.

Sometimes the overcloak is tacked down to the undercloak by cutting a piece out of the turn-up lead, as shown at F, E, R, Fig. 1,288, and then by cutting a tack in the stand-up lead of the undercloak to turn back over the overcloak. Another method is by the use of a strap of lead as shown at I, Fig. 1,268.

Bay Windows.

Fig. 1,294 is a plan showing the method of marking out the lead in one piece, suitable for a bay window having a flat top and walls all round. Fig. 1,295 is the lead turned and worked up ready for fixing. A, the plan of bay; B, the front of bay, and D, C, the two sides. It often happens that the side or end, E, is too long to allow of the lead being put in one piece. Then it is a rule to have a sunk joint, as at J, Fig. 1,352 (also at W, Fig. 1,353 and Fig. 1,302), and wiped true and level through the centre of bay. When this joint is used see that it is wiped clean and square in the angles (see Fig. 1,302, and description), for nothing looks worse than a lot of lumps and rounded angles where the line should be straight and square. It often happens that there is a casement window to walk out on to the bay, and it is not at all pleasant to have a lot of lumps of solder to walk upon; besides, these lumps of solder often prevent the water running off the lead. Sometimes you can work in a drip when the top is not required to walk upon. This makes a very good job; but for my part I

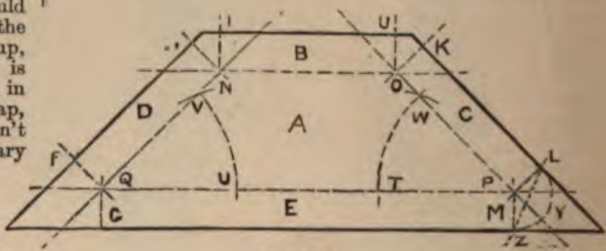


FIG. 1,294.

like the joint best, because, as a rule the pipe leading from this bay is too small to allow a few leaves, or a small piece of mortar, &c., to pass it; the thing becomes

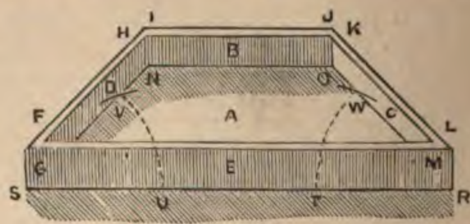


FIG. 1,295.

blocked up, and an overflow follows. (This is no excuse for putting in too small pipes.) But your bay is in one piece, and with the usual turn up of 6in., it holds a good quantity of water. Besides, you can then put in an

overflow pipe, 3in. up the side, or just below the level of the sill; but, if you have a drip, it is ten to one if you can get more than 1½in. in depth, and then the overflow would become next to useless, for being fixed so low it also has the chances of becoming blocked. The following is the method of marking out bays for bay windows for soldering up angles, or corners, as we call them:—Suppose the brickwork to be all round, Fig. 1,295. First, measure the height you can go up the wall (to suit the flashing you can go 6in.), then mark the 6in. along the side of the lead, as at M, G, Fig. 1,294, and snap the line P, Q. Say you can go 6in. all round. Next take the width from back to front, as at U, N, T, O, this is 1ft. 8in.; measure this off on the lead, as shown, and snap the line O, N. Next take the bevel of C, M, T, Fig. 1,295, and place this on the lead at T, P, C, Fig. 1,294, and snap the line to this bevel, P, O. Next take the length of R, S, Fig. 1,295, this is 5ft. 10in.; then measure and set off this distance on the lead, as at Q. Take the bevel and take the angle U, S, F, Fig. 1,295, and place it on the lead at U, Q, D, and on the point of measurement snap the line Q, N. You have now transferred the plan of the bay on to the sheet of lead. Let us now use our geometry and see how to take the angles without the use of the bevel. Take a pair of compasses, place one leg on the end of bay at R, Fig. 1,295, and stretch the other out as far as you can towards W, then strike the curve T, W; do likewise from the point S, as shown at D, U. Be very particular about the points at R, S, &c. Next, from the point P, Q (the length of bay), Fig. 1,294, strike the curve W, T and U, V, then with compasses measure from T, as a centre, Fig. 1,295, to cut the curve line at W, and place this distance on the lead, Fig. 1,294, by first placing the leg of the compasses on T, and striking the arc W. Next measure from U, to V, Fig. 1,295, and strike the arc V (it is very likely to be a different angle to that at W, R, T, if so, you will have different lengths from S to D, R to W), also transfer this to the lead, Fig. 1,294, as before. Then these angles on Figs. 1,294 and 1,295 must be the exact shape of each other, which may be worked first on the real place, then reduced to any scale and put on paper, as Fig. 1,295, and again enlarged on to the lead. Another way is to take the shape with a templet. Of course this must be true. It is also quickly done with five pieces of slating batten. Cut the longest length first, then the front, N, O, Fig. 1,295, then the two ends, and nail them together; then nail one end of the fifth piece on the end batten at N, the other end on the long batten at E. This forms a triangle, which cannot be ricked or put out of shape without first breaking. Well, now you have the plan or shape of the lead, do you intend to boss up the corners? If so, you can cut a lot off the corners at F, G, L, M, Fig. 1,294, before you commence working it up. It will save you a lot of labour. The safest way to mark this for cutting off is to take the compasses and mark the part of a circle, Y, and cut it to this, but you will have a lot too much stuff to work up. If I were doing it I should cut it at the line Z, by first setting up the line M square to U, T, and the line L square to the line P, W. This looks too short, but it is plenty of stuff for the corner, and will come up with a quarter the work. The corner, J, K, is also cut this way, excepting the curve or part circle. Don't you try this short cutting unless you are well acquainted with drawing up sheet lead corners, but allow yourself plenty of stuff.

Cutting this for soldering up, having the shape on the lead, lay the square on the intersecting point P, Fig. 1,294, and square to the line O, P, draw the square line L. Also place the square on the line, Q, P, close up to the intersecting point P, and draw the line M; likewise the other two corners, and cut same to these marks. If you require a little, say 1in., for a lap, of course leave this much on at each corner. The laps should be left on the two ends, because they are the last to be pulled up.

Breaks in Gutters, &c.

This is simply a return angle, and is illustrated at Y, Fig. 1,298; also at E, F, Fig. 1,262. On examination of the latter figure it may be seen that this gutter is one suitable for a place where the chimney gutter comes through the main gutter. We will say that the chimney is 3ft. long, and protruding into the gutter 4½ inches. Of course, in this case the piece of lead must be taken out as shown at O, S, T, M, Fig. 1,263, and the lead turned up in the usual style, but at the corners, as at W, X; the lead must be cut rounded externally, as at Y, Fig. 1,296, to make up for the deficiency in the lead as shown from E, to W, Fig. 1,262. Fig. 1,296 illustrates the lead as it

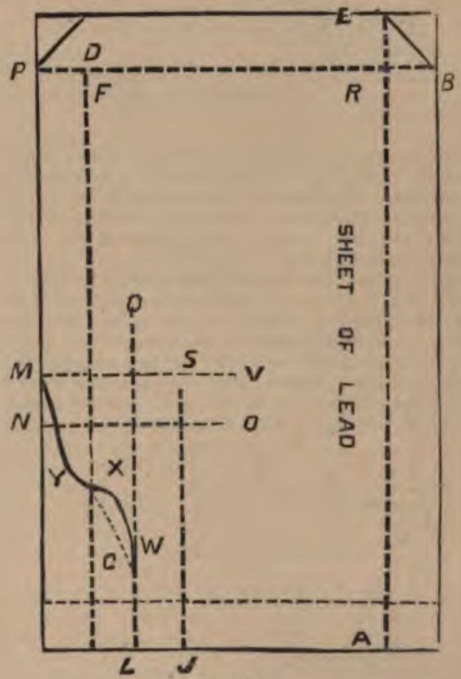


FIG. 1,296.

would be marked out, or a gutter having one break, as at N; round this point you see it is important that you get sufficient lead to allow for the working of the turn-up, which must be done very cautiously. Fig. 1,297 shows the method of working the stand-up lead, as at S, N, U, L. If you cut this out without due consideration, the chances will be that you will cut it too small, and in order to get the lead up as at S, U, N, Fig. 1,297, you will have to strain it, which can be easily told by the lead being thin round this particular part. When working up this break, work up the lead even and true, knocking it from the external part, as at S, U, Fig. 1,297, towards L, and do not flog the angle N, scarcely at all, but remember to get all the stuff you possibly can from the outer parts, and when necessity compels you to strike the lead between S, and N, or U, and N, strike it from the edge part downwards towards L, so as to thicken it, remembering not

to strike it harder in one place than another. The secret is to thrust your lead from S, U, towards N, with even blows, and to get it into a little easy bulge, as shown, so that you will be sure of having sufficient lead when the time of squaring up arrives.

You see at M, Fig. 1,297, a corner. Now a good plumber will work the stuff from this corner (if it only be 4½in. or so break) towards the break as at U, N, L, and so work the corner and break up at once, thus saving time.

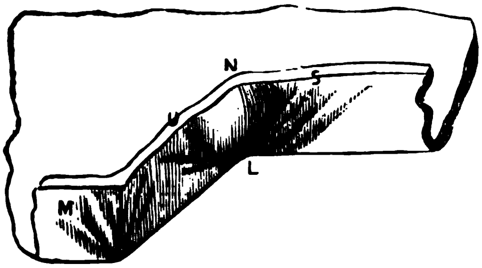


FIG. 1,297.

Sometimes you will find it necessary to form a break, as shown at Y, Z, Fig. 1,279. This is, say, a small break 12in. square; and, upon examination, it will be found almost useless to attempt to work up the sides should they be of the ordinary height, simply because you have not sufficient stuff to do so.

For example from X, to Y, is 6in., and also from 1 to 2. From 1, to Y, is 12in., so that the two sides alone will take all the stuff, leaving nothing for the ends. When such is the case, or anything approaching such, do not attempt to work it, but cut the two sides or two ends and solder a piece in and up the angle. But suppose your break to be, say, 8ft. long by, say, 14in. wide, or something of this sort, as at W, X, Fig. 1,262, then the break can be worked in the

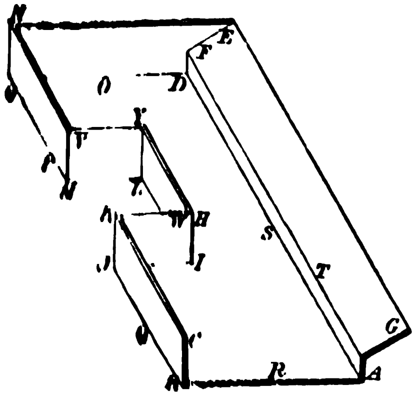


FIG. 1,298.

usual way. Fig. 1,298 illustrates a break gutter, commonly found with the one side as F, G, worked partially square up and partially on the rake, for the slates, &c., and well shows how the work should be finished at V, L, Y; W, I, J, K; B, C, A, G, D, &c.

Chimney Gutters.

Fig. 1,299 shows the chimney gutter on roof. Notice, on the left-hand side, you will see at A, the chimney gutter from end to end, showing the method of finishing at the drip J, and also shows the lead at H, going up

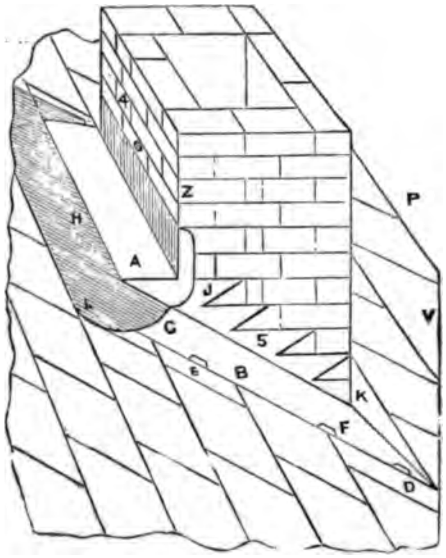


FIG. 1,299.

under the slates and over the springing. For section of the chimney gutter on the right see Fig. 1,300, which shows the method of working and fixing the springing. This springing should not come past the line of chimney

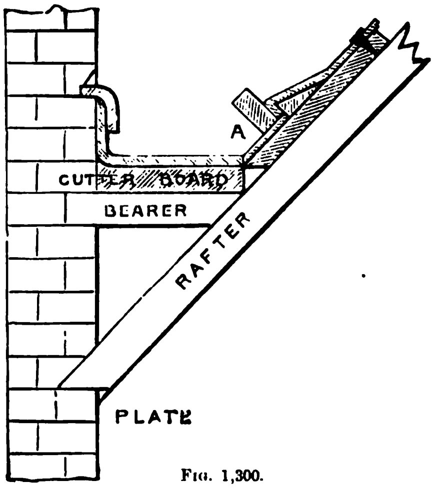


FIG. 1,300.

brickwork, or, in other words, project beyond the drip; and when fixing the lead up along the top of the springing board, never nail [illegible] or 12in. of the ends, as the slater will requ[illegible] to fix his under slate—

viz., the slate under E, Fig. 1,301, &c., which, if the ends of the gutter are fixed, of course could not be done. The

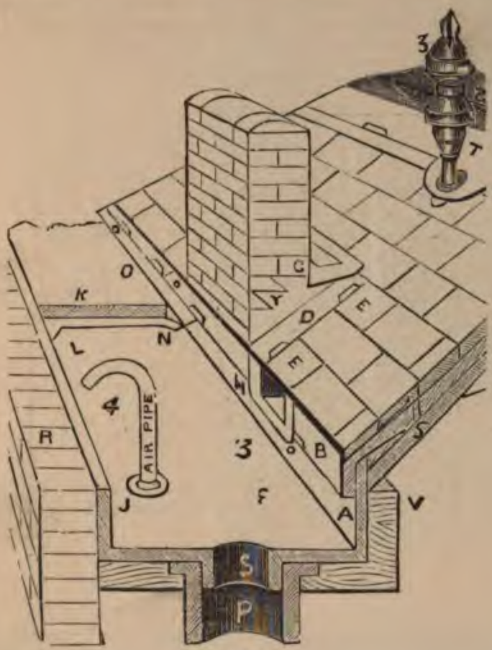


FIG. 1,301.

ends or drip of the gutter A, J, G, Fig, 1,299, are worked down after the flashings, G, B, J, F, K, are fixed.

Working down Chimney and Skylight Gutter Ends.

First trim off all the lead not required. Then take a mallet and drive the lead down at the same time, taking care not to strain it more in one place than another. Where you can, bend down the stand-up part of the lead as you did at Fig. 1,287, and work this lead up in order to get more lead at J, Fig. 1,299, or at G, Fig. 1,301, or as at K, Fig. 1,357. Now, having bent it to as near the shape as you can, take the dull chase wedge, Fig. 1,278, or that shown at Figs. 1,290 and 1,291, and draw all the lead you can from the outer part of the drip into the angle or angles, using the mallet where you can, and work the lead thick in the angle, taking care that it does not spring—viz., it should be held down firmly by the mate or otherwise, and when worked sufficiently, square the angles and trim them off as shown at L, G, J, Fig. 1,299, or K, Fig. 1,358.

Trough Gutters.

These are simple gutters, made to carry the water from front, middle, or back gutters, to some other part of the building down to stacks of rain-water pipes. They are usually from 9in. to 11in. wide, and from 4½in. to 9in. deep. The outlet of one is shown at H,B,3, Fig. 1,301. These gutters often range from 20ft. to 60ft. in length, and when the lead is put in pieces, the joints should be wiped flush in the bottom and sides, as at Fig. 1,302, so that the troughs may drain themselves dry, which could not be the case if the joints were raised patches of solder. Fig. 158, Vol. I., illustrates the method of sinking the joint, and

FIG. 1,302.

Fig. 1,302 shows the solder at W, which can be worked out of the angle with a feather-edged bit of stick, about 3in. long and 2½in. wide, as shown at Fig. 159, and Figs. 1,352 and 1,353.

Cesspools.

These are receivers of gutters, and answer the purpose of a lead head. They are simply boxes sunk at the foot of a gutter, as shown at A, B, Fig. 1,310. A, illustrates the outlet, which, in this case, is soldered into the bottom; B, the outlet, which may be fixed in the side. In this diagram it will be seen that two or more gutters are brought into the cesspool. You see the gutter D, discharges itself into it, also the gutter E; and another gutter can be brought through the wall under the coping-stone.

A cesspool is shown at Fig. 1,304, as it would appear when made up for a single gutter; and Fig. 1,305 illustrates the method of marking and cutting out the lead for the same; it also shows the soiling W, and the shaving line I, J, K, &c. First you want the size of the cesspool; measure the bottom each way; then the longest end; then the two sides. If one should be longer than the other, mark left and right, or south, east, west, or north side, and take the lead, Fig. 1,305, which must, or, at least, would probably be more economical if cut in one large piece, or as it may suit yourself.

In this case one piece, though, if in large sizes, the most economical for the lead, of course, would be to put the end, E, G, in a separate piece. However, here you have a piece of lead large enough. Mark the sides at dotted lines, G, H, E, F, then the ends A, B, and C, D. Leave enough stuff (about ⅜in.) to turn round to hold the sides together whilst soldering, which can be trimmed off afterwards. E, G is the end having the extra stuff for turning to hold the sides shown in dotted lines, E, R, the other side should be the same, G, O. Take the shave hook, and with the point of the blade and iron straight-edge scratch a deep groove, or the lead half through, just where you wish the lead to bend or turn round. This makes it work or turn easy, and will be plenty strong enough to hold it. Serve the inlet end, F, H, the same. You see that the two sides, C, D, protrude forward and over the inlet end, H; therefore you must cut the sides accordingly, and the end, if turned over, as at P, Fig. 1,304, for the nailing, longer than from L, to M, or J, to N, Fig. 1,305. Also, the top of the sides at D, B, must be longer than K, L, as shown at M, D, and C, N. Now, having the right sizes, soil same about 5in. from edges all round, as at W, W, and dry off with shavings or otherwise. Shave it clean to an inch or 1½in. wide. Then pull up the two sides and set it in. Next pull up the end E, G, and set this in also. Turn th projecting part, O, R, S, T, to hold up the sides; next to D, M, C, N, on one side, and pull up the inlet end, F, H, a set this in; next, turn down the nailing flap, P, to sh of that, Fig. 1,304, and fix it for soldering, which may done either in its place or on the bench.

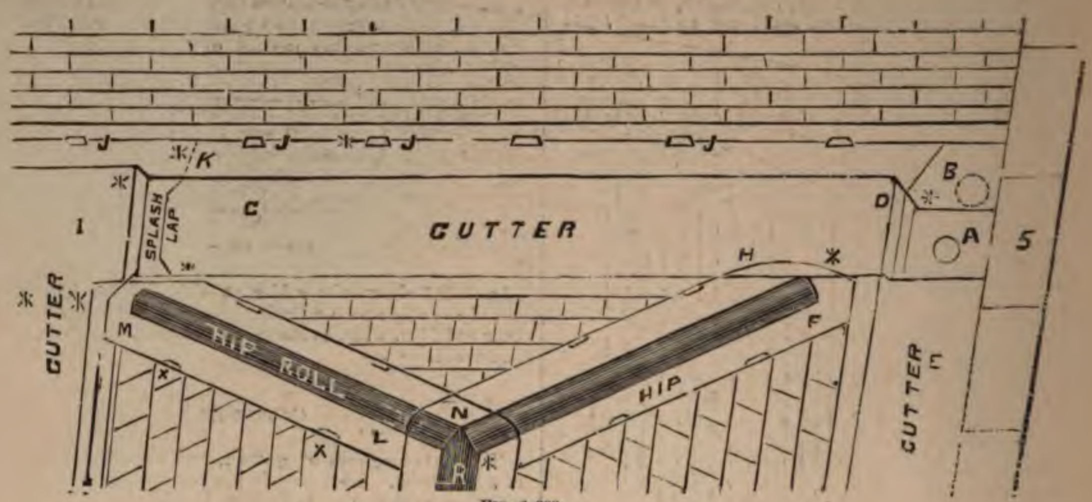


FIG. 1,303.

Figs. 1,306 and 1,307 are also cesspools, but very differently cut out. You see the end, A, E, B, G, I, K, is on the bevel. The care required in cutting this out is having splayed sides or ends, are apt to cut these splayed parts too short—as also they do in cutting the lead for a foot of a coffin

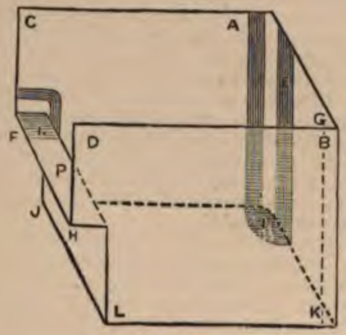


FIG. 1,304.

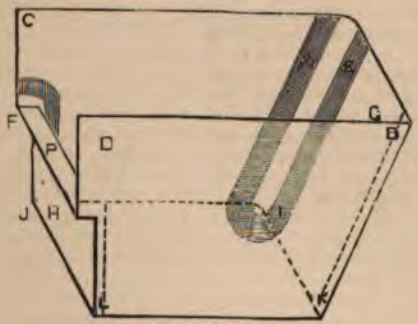


FIG. 1,306.

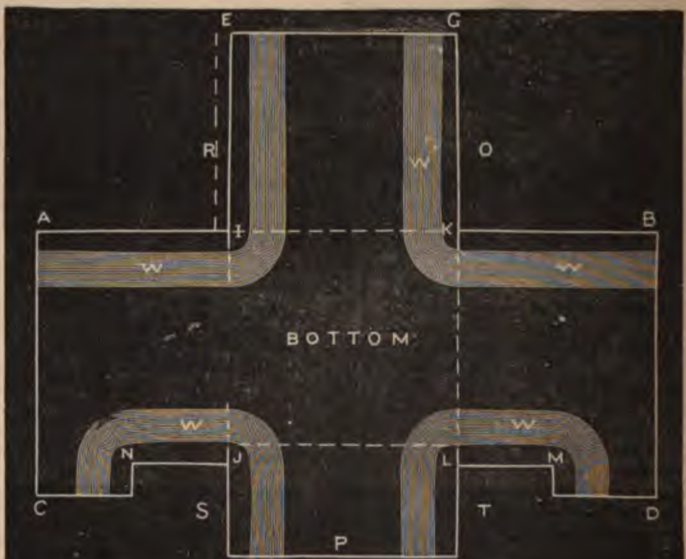


FIG. 1,305.

not very much, but still it must receive due attention. To make sure, always measure from the top at E, G to the bottom at I, K; then take the bevel for the sides at B, K, A, I, with the bevel, and cut it accordingly; prepare and solder as above. The reason why I have written upon the second cesspool is because so many men in making cesspools,

Hints for Cutting Leads for Coffins.

They measure the sides, and take it for granted to be the same all round. The foot being on the slope as at G, Fig. 1,30 longer, so that the top part of the side wil B, D, Fig. 1,307, and so on.

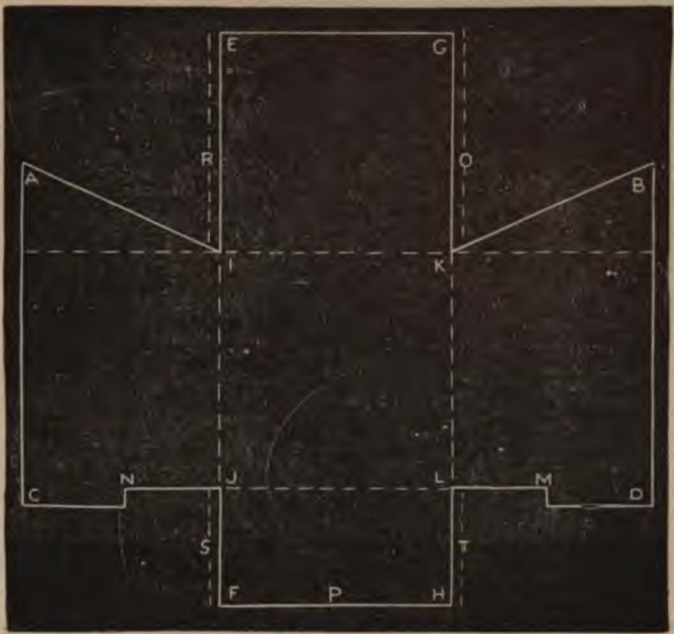


FIG. 1,307.

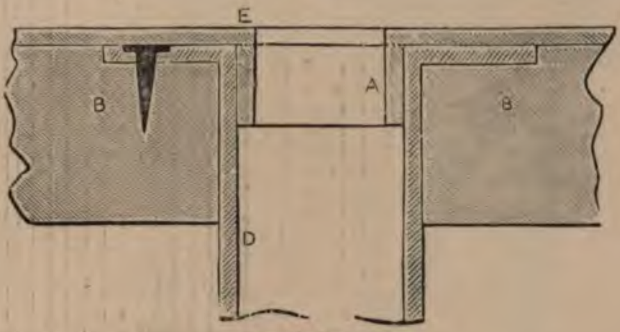


FIG. 1,308.

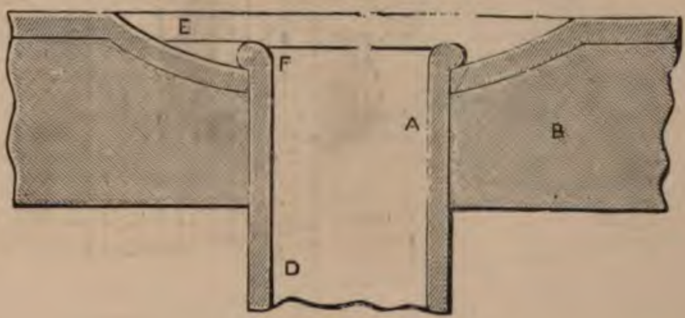


FIG. 1,309.

Now let us again refer to Fig. 1,303, and see how this cesspool is fixed. In the first place, you require to know whether the outlet A, is to be in the bottom or in the side, as shown by the dotted lines B; if in the side, it must be wiped in; but if in the bottom the outlet pipe may be first turned down into a rebate and nailed, as shown at B, B, Fig. 1 Then the cesspool bottom may be worked down as and E, will be the bottom of the cesspool; or it dished down and wiped in as at E, Fig. 1,309. done when an overflow pipe is also wiped in th

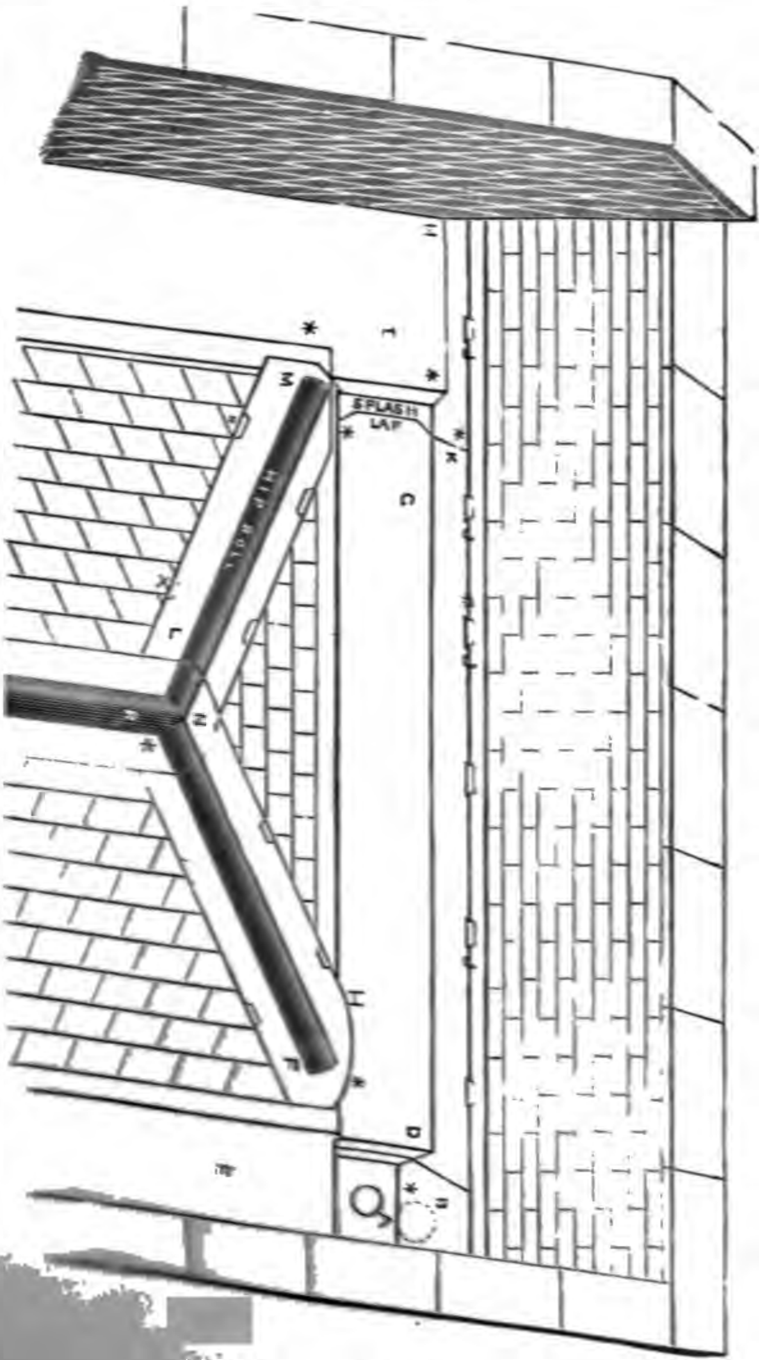


FIG. 1,220

not ver[illegible]
make s[illegible]
bottom a[illegible] any rate, [illegible] to the eye; but whenever the
A, I, with[illegible] to be [illegible] it should always be [illegible] down,
solder as [illegible]
second com[illegible]

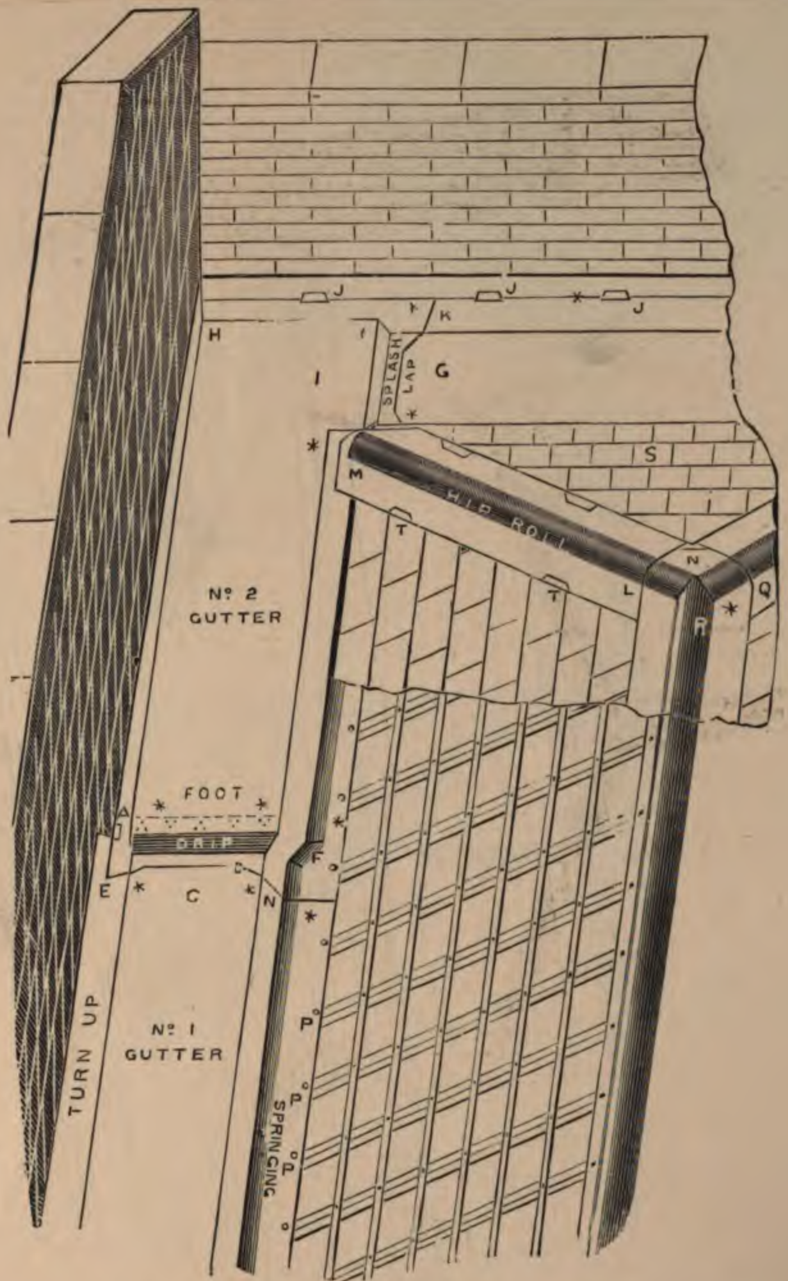


FIG. 1,311.

Arranging Gutters.

The plumber is often called upon to arrange the woodwork for lead gutters, as by doing so he can often save both material and labour, not only for the lead work but also that of the carpenter, and will often make by far better work. For instance, he can sometimes use a drip where most likely a joint would have to be wiped, or *vice versâ*, which may be the means of enabling the plumber to cut his lead to advantage. For example I will nov refer you to a job carried out by myself. At Fig. 1,31 and at G, H, may be seen a long parapet gutter, abou 9ft. 6in. long, which, if it were carried up to the wall as a. H, would be about 12ft. long, but by having the drip where it is, it shortens the gutter and is none the worse for it: but it may be that the gutter H, I, may be too long, then this gutter may be worked to advantage, and these are the

(See Step Flashing.) Sometimes these gutters are made wide enough to allow a man to walk up, and more resembling that shown at A, Fig. 1,315, which is very handy for the sweeps and others to climb to the top of the chimney. Some slaters bring their slates to entirely cover the lead gutter, especially if the gutter is a narrow one. Fig. 1,315 at X, Y, Z, shows the finish of the lead ridge over the tops of these secret gutters before the flashing is put on, which in this case is a job done by myself at Blandford Square Convent, twenty-five years ago, and flashed with herring bone flashing.

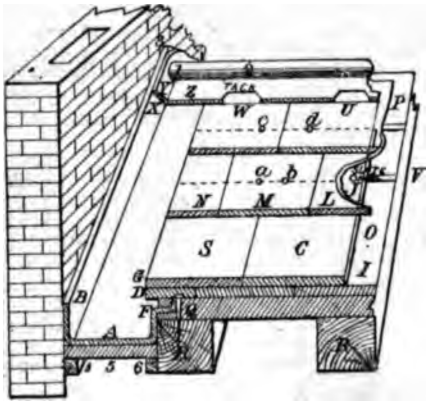


FIG. 1,315.

Sometimes it is advisable to fix a fillet under the slates at D, Fig, 1,315, in order to give them about a ½in. tilt from the wall towards the centre of the roof, or a welt may be turned on the lead as at Q, but of course nails must be kept on the outside of such welts.

By referring to B, L, Fig. 1,314, you will observe that the lead is brought a long way under the slates, which I consider a waste, for the simple reason that the two slates at K, &c., must of necessity be nailed on through this lead.

When finishing these gutters you want a narrow dresser, or a good piece of hard wood, 18in. to 2ft. long, the width of the gutter, then with a large hammer you can drive the lead into its place, that is if you have set your lead up properly at the outset. Should the gutter be a very narrow one, say 2in., you can first of all turn up the lead as at E, then fix it on a scaffold board with a clout nail or two near the top edge, then lay the stand up lead flat down under the board, and bend the remaining part of the lead round the other edge of the board, which will give you the two bottom sharp edges. Now see that the joint of the brickwork is raked out, and then you can take the board and lead up and place the work in its place. Fix the board so that it will not rise, and then turn down the underlead B, L, sharp over the springing or other edge, and fix it, when the board may be taken out, and the back stand-up lead permanently fixed with wall-hooks, &c., ready for flashing.

Stone Coping or Cornice Gutters.

Fig. 1,316 is a level gutter for copings and cornices, which goes up the roof as at J, K, being the roof or springing board; B, is a piece of quartering, which forms the back of the guttering; H, is lead for fixing the timber L, to the stone work F. You see the lead is put in over the quartering B, and worked down over the front as at E, and held in position with the dots M, M, it also is dotted along the front as at E.

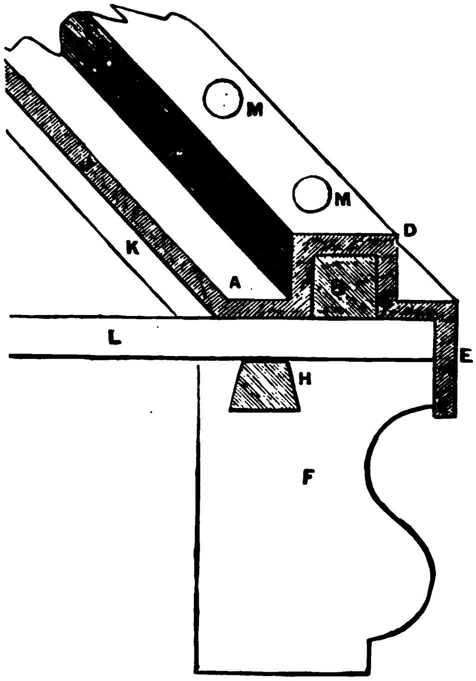


FIG. 1,316.

Stone Channel Gutters.

A stone channel is shown at Fig. 1,317, which almost explains itself, and the drawing is from some work which I personally did many years ago at Blandford Square Convent for Messrs. J. & E. Bird, builders, of Hammersmith. The channel is cut in the top of a stone cornice, the lead is taken over the springing and up roof, and fixed with dots, by first having holes cut in the top as per section M, and filled up with lead for soldering to. The lengths are soldered together by first sinking the stone for a joint.

The method of working this lead into shape is to first get the exact (or nearly so) width for lead, then set up the square as at D, place the lead on the top of gutter, and then place a board on same to keep it in, and against springing, press on this board and bend the lead over the springing and up roof: dress it down and nail it there. Next you want a piece of wood like the shape of the channel; a soil pipe mandrel is a good tool for this purpose. Place the board or quartering close up to the springing, and out of the way; then place the mandrel on the lead and over the channel, and bend the lead up and down, at the same time let the mandrel be well pressed down, this works the lead into the channel, then dress it there with a piece of hard wood having a handle something like a dresser, but ... face; work the joint down on brown pap ... The ends are best finished by solder.

After this solder joints, and work down the length over B, and the channel is complete.

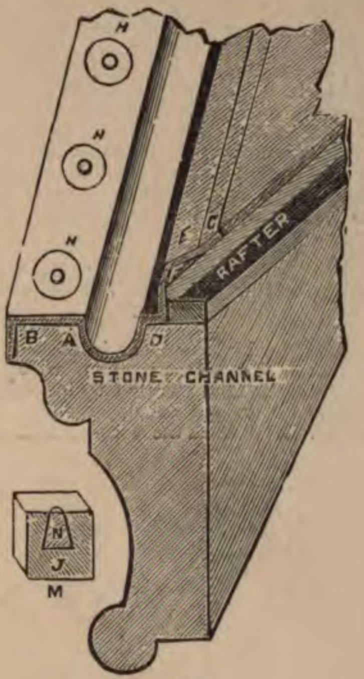


FIG. 1,317.

These lead channels stand for ages, notwithstanding they are exposed to the heat of the sun. The stone keeps them cool.

Hanging and other Flashings.

This is the simpler kind of flashing, and is about the first thing to give a lad to do on roof work; nevertheless, it should receive due attention. The lengths are generally cut across the sheet from 4in. to 8in. wide; then the edge is turned over, about 1¼in., as shown at the flashings on stand-up of the gutter, Fig. 1,300; also at J, Fig. 1,310, so as to go well into the joint of the brickwork, for holding it to the wall.

Bale Tacks.

These are tacks hung on to the stand-up part of the gutter, as at T, Fig. 1,332, and also at J, Fig. 1,310, and should be fixed every 18in. or 2ft. apart, and cut out of, at least, 6lbs. or 8lbs. lead.

These tacks are generally turned over an inch or so, to hang upon the stand-up side of the gutter, or sometimes they are fixed to the wall with wall hooks, nails, &c. When fixing the flashings into the joint of the brickwork, use plenty of good wedges, or wall hooks, say, every 12in. or 18in. apart, and fix a tack at the end of every length of flashing, or better still, cut your flashing so that you have sufficient lead to trim off to a straight line, and to form a tack on the end of the undercloak to clip, or hold the overcloak snug up to the undercloak, a very expensive method, but it is practised on good jobs. The hanging flashings are well illustrated at the section of gutters throughout this work, especially at the flat at T, S, Fig. 1,375.

Flashings.

It is that kind of lead work which we see up the sides of walls, one side (called the wing), or the bottom of which lays upon the slates. There are various kinds of flashing. Some have the under part of the lead, which rests upon the slates, or that which lays upon the roof, cut in small pieces, called soakers.

Soakers.

See Figs. 1,334 and 1,335, and T, T, T, T, Fig. 1,356. In such cases the lead which lays upon the slates is not seen, as each piece is worked in with the slate. This is acknowledged to be the best kind of work so far as regards the keeping out of the wet. When these soakers are used small steps are cut and bent to the shape of step, Fig. 1,318. You see that if the mortar is out of the joints, D, about 1¼in., and the lead cut and bent to the shape of step, that you can hang the step to the wall with wood or lead wedges, driven into the joint in such a manner that it holds or wedges the turned part of the step, T, to the brickwork, the bottom part of the step then covers the stand-up part of the soaker, as at H; but you see in this

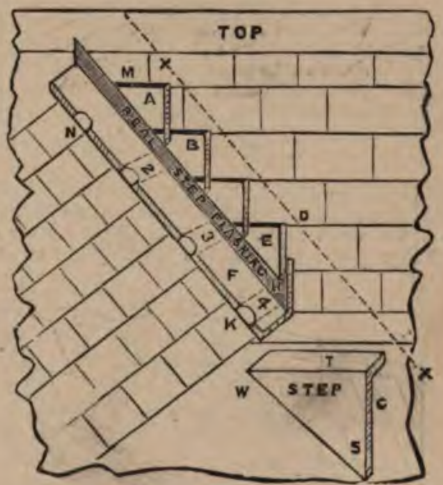


FIG. 1,318.

case that part of the lead, which lays upon the slates, is in one long piece. It is also upon the slates, but as regards the steps this makes no difference whatever; this is the original or real step flashing. When the underlay (as it is called), F, is in one piece, the wing, F, must have plenty of tacks, as at N, K, to keep it from coming away from the brickwork. These tacks are nailed on the boards or slating battens, or they may be fixed by driving a long nail through the lead, and between the slate and brickwork, or by turning the end about 1¼in. at right angles, so as to drop down between the wall and the edge of the slate, but care must be taken that this clip fits tight between wall and slate. Another method of fixing the tacks is by wedging them tightly into the joint of brickwork, or wall hooks may be used instead of w Always place the tack at an angle to the line that the water will run down as it were fro towards the part seen at N, K, and not as dotted lines, 2, 3, 4, as these dotted lines ar

that the wet will run down the tack towards the wall, just the reverse to that which should be. The sides are fixed by driving in nails or wall hooks to hold them in their position. When you cut your steps for this kind of work see that they will stand vertical, as at the heel, C, S, and at H, D.

Herring-Bone Step Flashing.

For this kind of work, see Figs. 1,319 and 1,320, at 5, B, each side; also see end of wall, Fig. 1,312, which shows how to fix your flashing under ridge roll, and how to terminate on gutter.

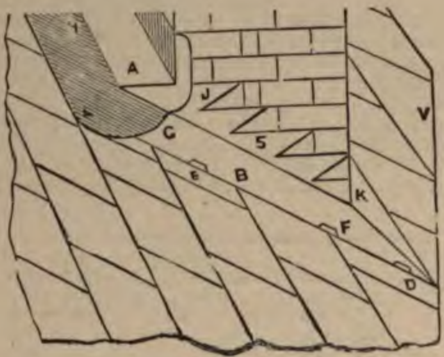


FIG. 1,319.

Again examine Fig. 1,312. This work well shows the undercut of step, J, *, which also shows a very long step, because the slates have very little pitch. After which look at Fig. 1,321, which shows the way to flash a curb

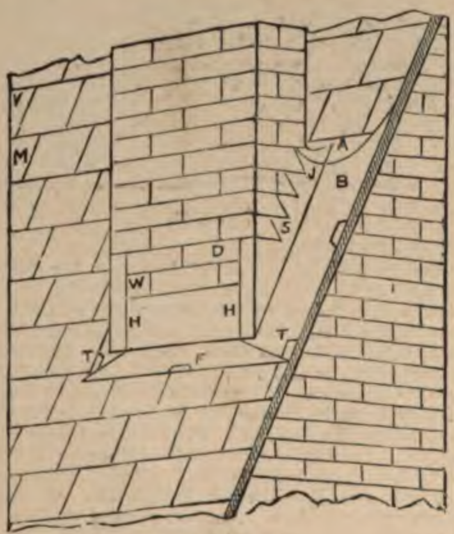


FIG 1,320

roof, as those recently done by me and one of my men at some new mansions, South Kensington. Now look at the steps on roof, and look at those on curb. The one on curb is near enough to be called an upright step, because the lead step is almost vertical. This causes the step to be short in the cut. Next look at those on the roof. They are flatter, and, consequently, longer. You should make this a point, to have your undercut to be as those on the roof. Never have the heel of the step cut vertical if you can help it, as it looks bad, unless it is the step flashing that we put in in separate steps, as shown at Fig. 1,318. Strictly speaking herring-bone work is the steps cut all in one piece, without the wing—that is to say, as that at Fig. 1,322. First fix the flushing apron or soakers to come up the wall 4in., and place the herring work over, as a flashing, with plenty of bale tacks to keep the bottom snug up to the turn-up of underlays, soakers, &c.

Marking, Cutting-out, and Turning-up Step Flashing.

Step flashing should be cut out in about 7ft. lengths across the sheet, and, at least, 13in. wide, but some plumbers only cut it 12in. Their step looks too short in the undercut. I have put on step flashing 20in. wide, see Fig. 1,323. First mark the turn-up line, E, F, 7in.

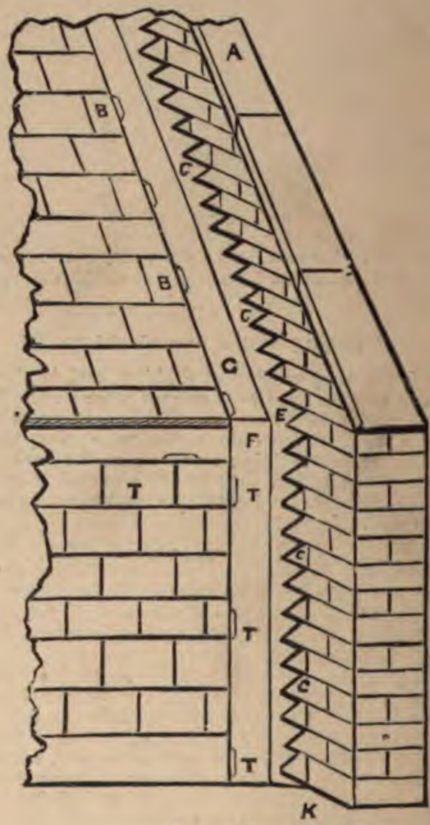


FIG. 1,321.

for the turn-up E, then mark the water line, B, C, 3in. from the line, E, F. Some only mark this line 2½in., and even on very sharp pitched roofs 2in., on purpose to get a good undercut. This is the lot of chalk lines; but if you

have a large quantity to do, it is much the quickest to have gauges made, so that you can first scribe the water-line, then the line E, F, and pull up without shifting your gauge, which is your pulling up stuff. One mark with the rule at each end in this case will answer. Now, having it marked out and set up, let us see what should have been done whilst you are preparing your work. The joints of the brickwork must go out, but they are not yet marked. The way to mark them out is done as follows:—Suppose you are to have 7in. turn-up, as at D, Fig. 1,324, and the water-line, B, C, 3in. up. If you look at K, Fig. 1,323, in this figure you will see a turn upon the step, as at T. Step, Fig. 1,318: this is the part you have to look out for to go into the joint of the brickwork. Measure up the brickwork from the slates 7in., say 8in. (because you require a little freedom in the joints), then 2in. for the water-line, which is 2in. up, say you have 1in. to play, for it is ten to one if they (the men doing the joint raking) don't try to do 1in. or 2in. less. Snap two chalk lines, as at X, X,

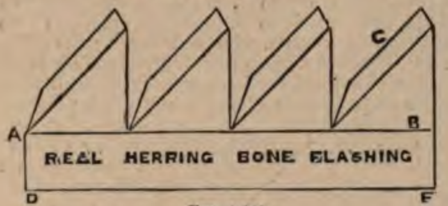


Fig. 1,322.

and H, M, Fig. 1,318. Between these lines have the joints raked out, at least, 1½in. all the way up. Next you want (if you are going to do much) a gauge or a bevel (the rake of the roof), and the top level with the joints of the brickwork. This is best made with a piece of ½in. board 18in. long, going to a point, as per line of brickwork, and to the rake of the roof. Now you are ready take your lead, Fig. 1,324, which, we will say, has been set up; place it against the brickwork in its place exactly where you intend to fix it. Place the new-made bevel on same, and with the compasses (set 1¼in. or 1½in. wide) draw the joint line, D, D, D, D, true to the joints of the

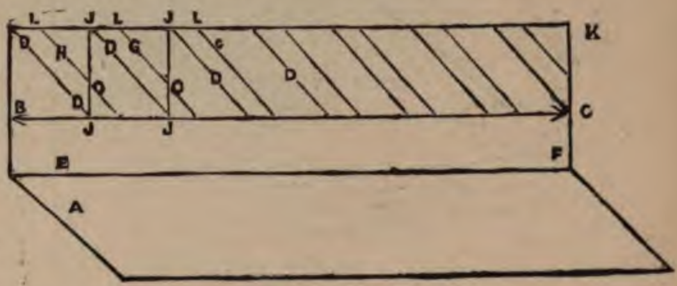


Fig. 1,324.

brickwork, as shown at M, *; J, &c., Fig. 1,312; and with the other point of the compasses scribe the turn-in or cutting line H, G, G, 1¼in. from D, Fig. 1,324. Do this from one end to the other, and draw the undercut line J, J, J, J, from point to point of joint line D, D; and where this line runs take the snips or shears and cut to this line, after which cut the line from L, to O.

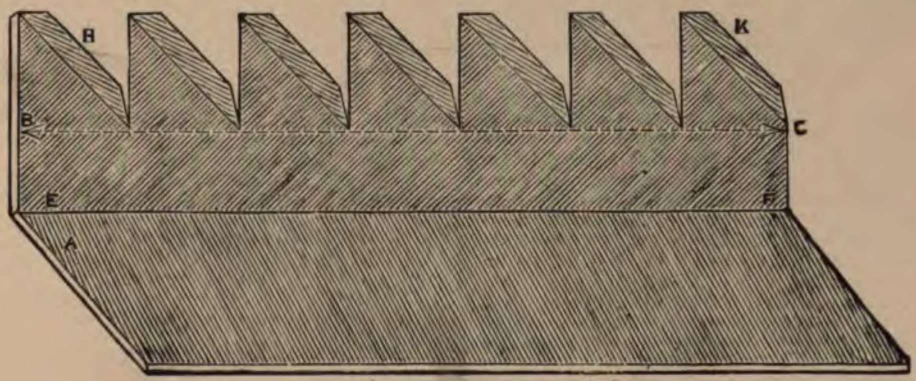


Fig. 1,323.

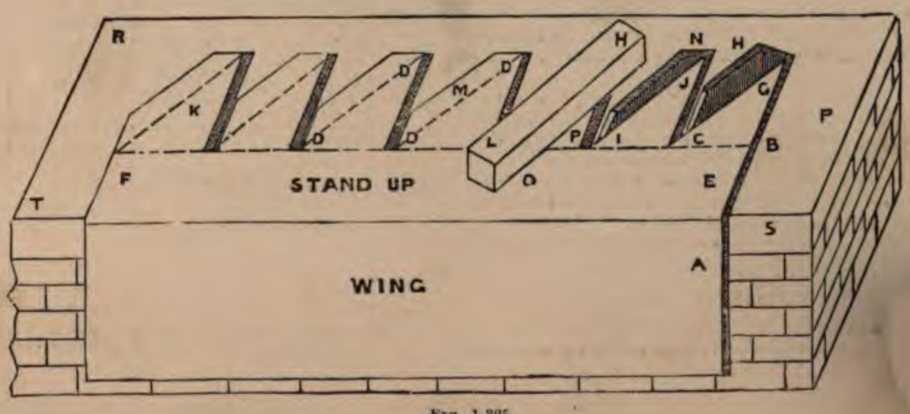


Fig. 1,325.

Shears, or Snips.

The best size for the snips for this work is 12in. in length, having a cutting jaw of 4in. The best way to do

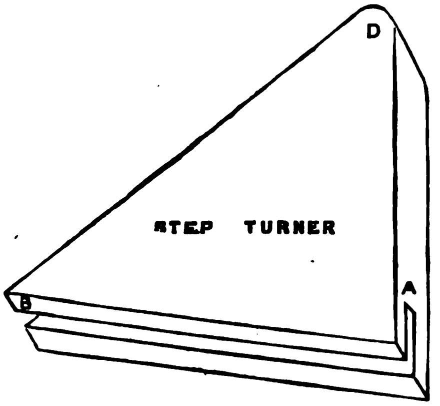


FIG. 1,326.

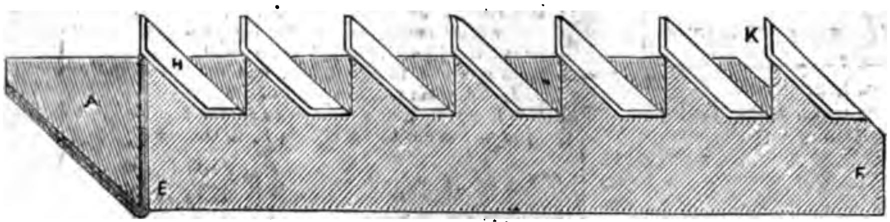


FIG. 1,327.

this cutting is to place it on a temporary bench, made with a scaffold board placed across two saw stools, or brickwork, as best you can. Having cut this to the marks, called cutting the teeth out, turn the lead over as at Fig. 1,325, face side downwards—viz., the side having the lines on. Now get a piece of wood, say 2in. by 2in., as shown at L, H, and place it on the joint line D, D. Now kneel on same with one knee, and with the points of the compasses pushed in under the turn-in part of the lead, pull it up, as shown at H, G, C, and N, J, I. Dress it up sharp with a small dresser, or, if you like, you may use the step turner, Fig. 1,326 (which is only a piece of hard wood having a groove cut in it at A, B). The turn-in part of the lead goes in the groove, and by pulling same over, bends the lead. This is handy to some plumbers, but I prefer my way with compasses for quickness, and certainly sharpness of angle. Fig. 1,327 shows the same thing for the right hand wall. This is all that is required, so far as regards the cutting and bending, or turning, as it is termed.

Step Turner.

I may here mention that this step turner is much the best when made with three plates of brass soldered together, the middle plate being about twice the thickness of the lead to be turned. Most plumbers, instead of taking advantage of the wood bevel for marking their steps, use a lath or straight edge and compasses. This may answer your purpose when only having small quantities to do at one pitch of the roof, &c.

Fixing Step Flashing Tacks, &c.

(*Also see Tacks and Bale Tacks.*)

Put 8in. by 3in. 6lb. lead tacks on every 2ft. or less, and wedge with either wood or lead wedges; or otherwise fix the tacks firmly to the slating battens, or by driving a 3in. or 4in. nail through the end of the lead tack, and between the brickwork and the edges of the slates. And after the work is properly fixed, trim the tacks, and work straight and true, and work all ends down as shown at N,2,3,K, Fig. 1,318, also at T,T, B,B, Fig. 1,321, and J,G, Fig. 1,312, T,F,B, Fig. 1,330. Always have a tack at the bottom of a length to hold the top and bottom lead together.

Lead Wedges.

Sometimes it is best to use short strips of lead rolled up wedge shape to make the wedges; but the proper way is to cast them as follows:—Have a wedge made to the size and shape of that at Fig. 1,328, with a bradawl for handle. Push this wedge into the sand, and fill up the hole with lead. You may make them by the thousand by fixing a number of these wedges on a board and pressing the lot in the sand together. Make other sizes; but they should not exceed ¾in. in length from C, to D, 1in. outside from C, to F, and 1¼in. to 1½in. from F, to G. Drive them into the brick or stone work home, without knocking the brickwork about. I like wood wedges best, if the pointing is done as it should be with good Portland cement. These wedges are cut by the carpenter out of a piece of pitch pine, oak, or floor or other board (yellow deal) six or a dozen at a time. For method of cutting same see Fig. 1,329. Have them cut all thicknesses. Some plumbers like them cut nearly or quite parallel, or without taper.

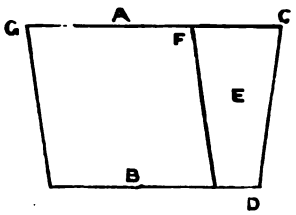
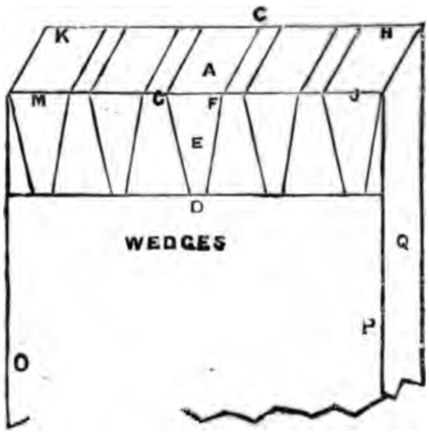


FIG. 1,328.



Grooved or Sunk Flashings, also Dormer Flashings.

(Flashing and Burning in Same.)

It often happens that the plumber will have to put the flashing into a groove cut into the stonework, as up the wall, at 4, 15, &c., Fig. 1,330; and when such is the case, this figure will clearly illustrate the method of fixing. This illustrates the best kind of flashing for fixing up a roof, having the joints running to the rake of the slates. Party walls are often like this, when the wall has to be raised by reason of being too low in the first place. This wall is built to the rake of the roof, and after the flashings are fixed.

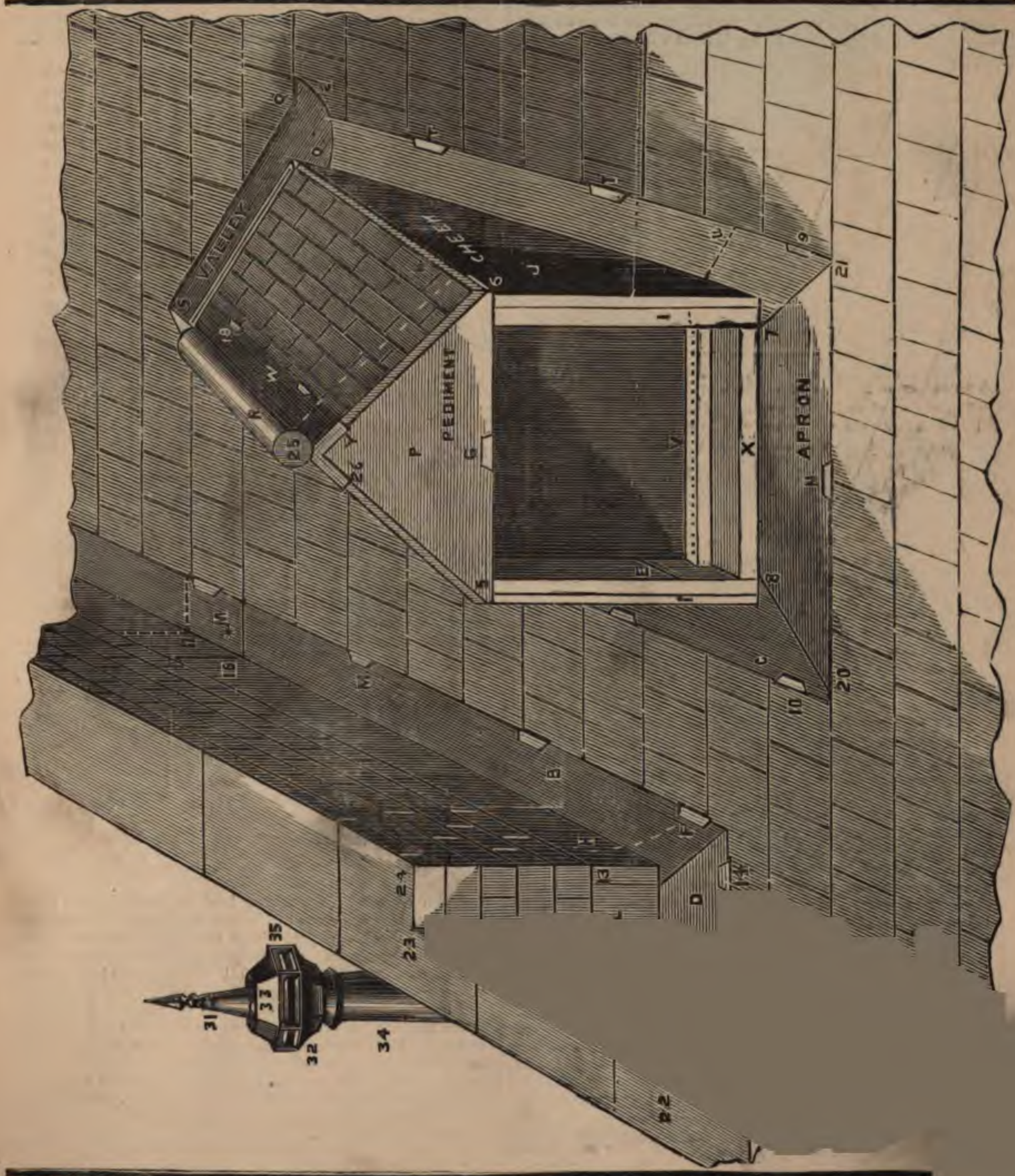
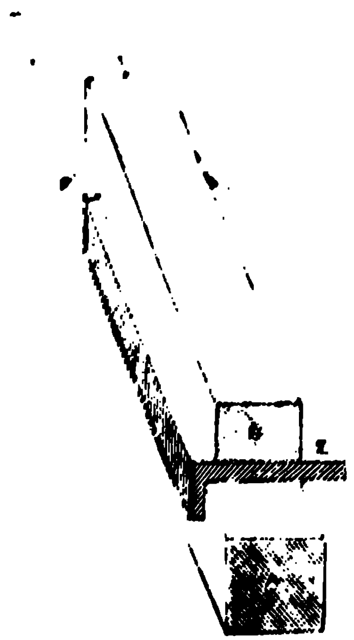


Fig. 1330

[illegible]

[illegible]

[illegible]



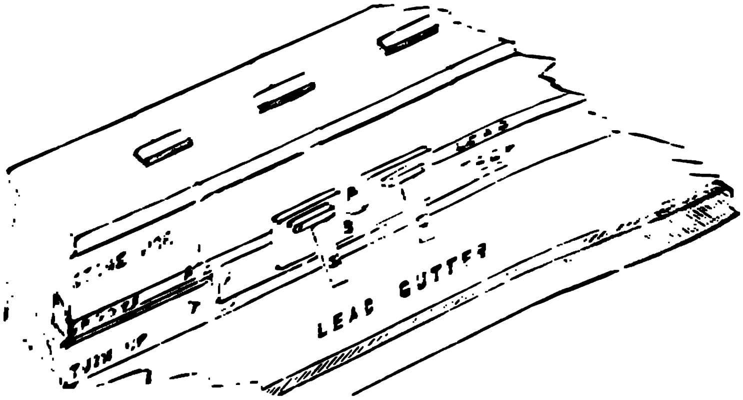


FIG. 1,332.

FIG. 1,331.

The Fig. 1,331 shows the method of flashing a wall up [illegible] roof. Having a break, as at K, 13, H, you see the flash[illegible] [illegible] goes on first. Then work K, 13, D, by first [illegible] the angle Z, as shown, and fix with tacks, &c. [illegible] placed close up to the wall, and a tack [illegible] Next turn up and fix the piece, H, B, [illegible] tacks, &c., as at M, M. This is in two pieces, [illegible] lap, as shown by dotted lines at M [illegible] figure you will also see that the flashing [illegible] is differently done to any of those to be [illegible] The lead on the pediment is brought [illegible] as shown at 5, G, 6. By doing it in this [illegible] done without thought of what follows) [illegible] casement part of the dormer from [illegible] sashes open inward then by all means [illegible] as it will shelter the casement; [illegible] the sill covered in such a manner [illegible] drive in. You may form a [illegible] water by turning the edge of the [illegible] The flashings of the [illegible] over the apron, as at 7, [illegible] T, T. This flashing [illegible] of the slates, Q, and [illegible] down over same, then

illustrates the [illegible] On the right [illegible] LEAD [illegible] will see the [illegible] B [illegible] having two pieces of [illegible] and a [illegible] hole P, which communicates with the groove [illegible] two struts to keep B, up against wall. To prevent these struts pushing away, place weights on each [illegible] or two bricks on each will answer. F, is the flashing, and T, the hanging tack as before said, called a [illegible] tack.

Fig. 1,333 shows the groove enlarged. The method to work is as follows: Get some soft clay. Place the [illegible] tacks on, and the lead flashings into the groove, as shown.

FIG. 1,333.

Let the edge of the flashing lead be bent sharp and as true as a line, and *down on the bottom of groove.* Next place the top of the board just above the top of the groove, and strut it up as shown; also weight it there. Stop up the end A, and pour the groove full of lead, well hot. After you have done pouring, go round the lot and trim it off, and caulk the lead into the joint or groove; turn your tacks, and the job is done. If you wish it to be thoroughly watertight, place some resin and a little touch in the groove before pouring, which forms a cement but very rarely used. Well caulk it where the stonework will stand it. The caulking is done with the point of a suitable tool of iron, something like a 6in. chisel, having a blunted [illegible] say to ¼in.

Underlays or Soakers.

Fig. 1,334 is a soaker or underlay, and is simply a piece of lead cut and bent to the shape, generally about 3in. to 5in. turned up; and B, from 4in. to 6in. to lay upon and under the slates. They are generally cut about 12in. long, but for this you must consult the slater, who will work them in for you, but see that you have them long enough to suit your work at the drips and turndowns. I believe that the soaker makes the best possible work, and another

SCALE 2"

FIG. 1,334.

thing the lead is out of sight, especially when they slate the cheeks of the dormers; not that I like to see this slating, for it looks clumsy. However, that is not our look-out; it is generally done to save expense, but don't pay in the long run. The best way to cut soakers is by cross lines, that is, suppose you wanted, say, 70 in number, 12in. long and 9in. wide, that is 4in. up A, and 5in. B. Then measure your 9in. up the sheet 10 times—90in., or 7ft. 6in.; then A, 12in. across the sheet seven times will cut a piece of lead 7ft. 6in. by 7ft. Now, having lined out this, take the long knife and cut them across each other. Break them up and make a gauge by placing two nails 5in. from the front edge of the bench, and turn them

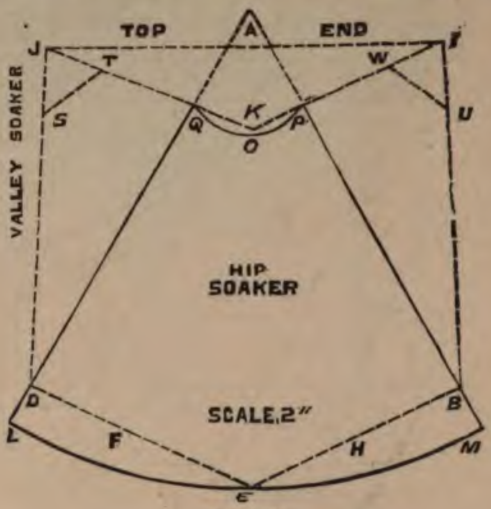


FIG. 1,335.

down to this gauge. This way you can cut soakers by the thousand. Soakers are sometimes cut to the shape of a cone envelope, as at Fig. 1,335. These are for hips, and sometimes for valleys, especially for tile work.

DORMERS, WELTS, AND BEADS.

These are sometimes covered all over with lead and at other times partly slated, tiled, &c., as shown in the large diagram, Fig. 1,330, which illustrates the top slated and the other parts leaded. Fig. 1,336 shows a simple dormer. The first thing to do is to make a template of the cheek B, or if you are pretty good at lines (that is, geometry), you can do away with the template; but I prefer it, unless you are well up in plumbers' geometry, especially if the lead is to be cut-out on the job. The dormer is, or should be, done as the slaters or tilers proceed with their work. For instance, the apron A, should be put on as soon as the second course of slate (in this case tiles are used) is above the sill. The tack T. is the first thing to put on; this is, or should be, 2½in. wide, and 7in. or 8in. long (*stout lead*), and nailed with at least 1½in. town clout nails into the bottom of the sill; or, if you can, on the batten over a rafter—at any rate, it should be fixed firmly. If the dormer apron should require more than one tack, put more.

New Tiling.

The tiles in Fig. 1,336 are laid with turn-down edges into small lead gutters, and are truly secret gutters.

Tacks.

(*Also see Fixing Step Flashings.*)

Tacks should be fixed for this class of flashings, aprons, &c., every 2ft. 6in.: for hips and ridges, every 2ft., and for curb lead the same. They should never be less than 2in. wide for narrow flashings, 2½in. for step flashing, wings, and aprons, and 3in. wide for hips and ridges, and should be cut out of stuff at least 2lb. heavier to the foot than the flashings, wings, aprons, or hips and ridges, and left long enough to properly turn, to hold the lead and trim off on the splay, as shown. If you have them too short you cannot get the proper power over them, to turn them tightly up against the edge of the lead—which in all cases should be cut the thickness of the lead out; so as to allow of the back edge of the tack at T, at bottom of apron, to come up flush with the apron line. The tack should be the last thing to turn, and after the work is trimmed off at the tacks should be trimmed off, the lead being over and cut on the splay, or, in other wor held at an angle, so as to cut the tack to This prevents your pulling the same up so ea wise. With a good sharp chipping knife, a the corners, also on the splay, as shown. things make the work look finished, and are

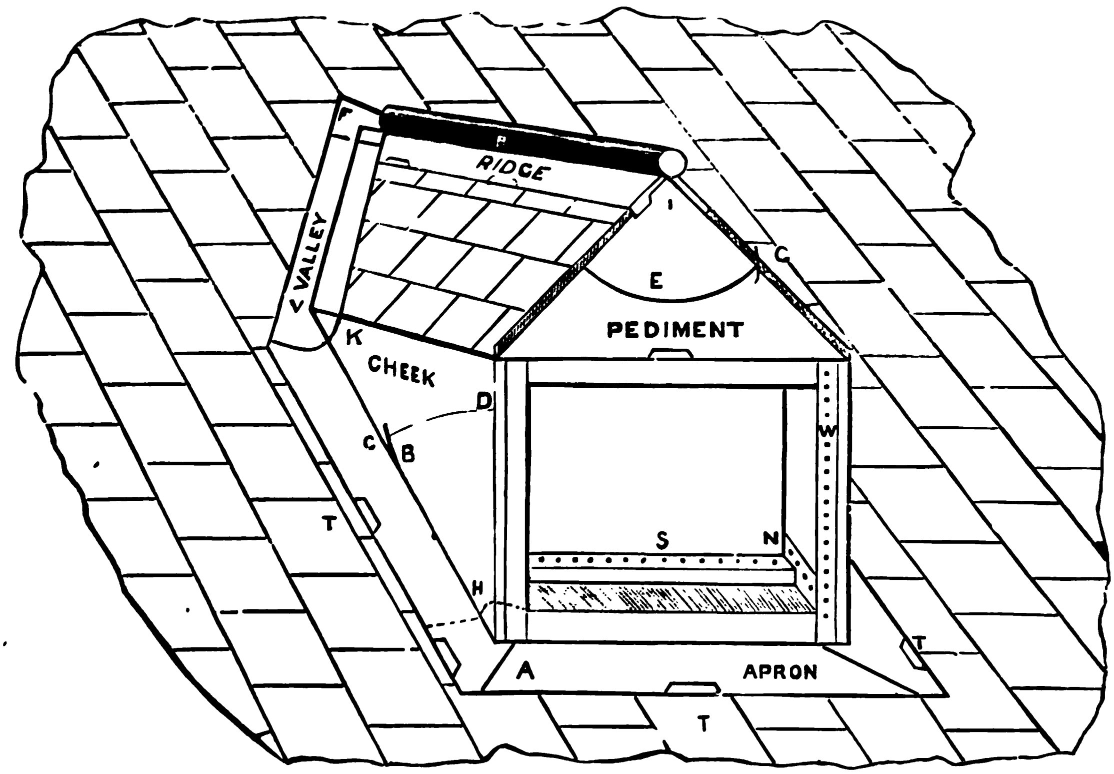


FIG. 1,336.

ficial to the work. When you are turning a tack be sure to pull it up firm against the bottom or edge of the lead which it is intended to hold. Strain it, as it were, to get it tight up, keeping the lead firmly down to its work as before remarked. Of course, you must fix your tacks firmly and to the nearest fixing, on to a batten or otherwise; but if not let into the sill or other woodwork it is likely to cause a lump. See that it is let in, and the nails driven into the lead in such a manner that there is not half-an-inch of the tack to bend back or to give way, or, in other words, let the head of the nail come right into the angle of the tack. Tacks properly put on should hold the lead stiff.

There are other kinds of tacks, which will be described as they are required. Let us proceed with the dormers.

Dormer Aprons.

The apron, Fig. 1,330, and also Figs. 1,337 and 1,338, should be the first thing to fix after the tacks. It should be cut 3in. longer than the width of the wings, or flashings of the cheeks; and if soakers, Fig. 1,334, are used, before the first soaker is fixed the ends of the apron, shown by the dotted line at H in Fig. 1,336, should be worked down upon the tiles, and round the side of the cheek in such a manner that it is impossible for the water to drive back, supposing the bottom end of a soaker or cheek not to be worked round the front of the sill. The apron in all cases should turn on the sill and go up to the bead or ledge, and be nailed as shown, with good copper nails. It should also be turned up about 1½in. and nailed to the jambs, as shown by the dots at N, taking care to have the woodwork cut away to receive same. This part should be closely nailed.

Close Nailings.

First paint the place with some good white lead paint; then place between the lead and the wood some stiff white lead; lastly nail the lead every half inch, or in some cases as close as you can together. If soakers are used the ends of the apron need not be so long, so with the flashings, but must be long enough to receive the soakers. The ends are in this case worked down, and the next course or series of slates, bed upon the top part or worked-down corner of the apron. If, however, the cheek has flashings, as at Fig. 1,350, then the ends of the apron form tacks, which answer to keep up the apron, and also to keep the flashing to the cheek or spandrel of the dormer. Of course this apron is just the same if the cheek has wings—which are in fact flashings. (See R, Fig. 1,337, T, Fig. 1,336.)

Cheek.

Dormer cheek, or spandrel of dormers. K, B, H. Fig. 1,337, is the cheek and flashing in one piece. It also goes up the gable or curb, and forms a curb lead under the slat... by the dotted lines. The cheek also goes ab... lley, when the end of the valley is not to b... a some cases in Gothic work.

The cheek must be cut large enough to come round the jamb to cover the front of the woodwork, and long enough to turn back over the nails, which are shown on the right hand side by the dotted line, and form a welt, shown at Q, H, Fig. 1,339 (to be spoken of presently), so as to protect the nail holes. Of course you see that this cheek should be fixed as the slaters go on, and before the valley V

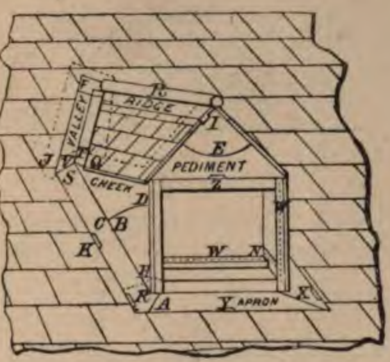


FIG. 1,337.

is fixed; the front or face piece E (known as the "pediment") is put on after the valley and cheek. It is cut sufficiently large to go under the slates 6in. The nails should be kept well back to within 1in. of the edge of the lead, and see that the slater does not drive his nails within 3in. of the front. Sometimes this lead, E, has to be dotted, but looks bad. Of course you will put a good tack

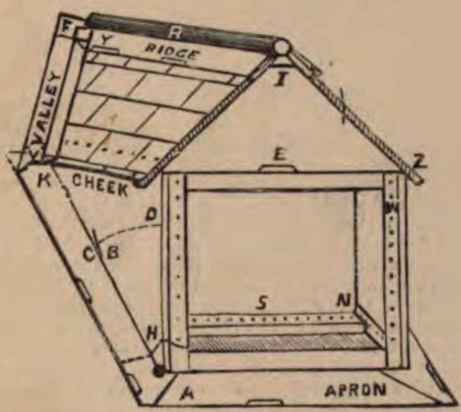


FIG. 1,338.

or two to steady the bottom. Soakers may be worked in with the slates up to the angle of the gable, and turned over the front of E, Fig. 1,337, then E, may be nailed all round the top, which makes a sound job. The lead may come right down as at E, Fig. 1,338, or a barge-board can be fixed over the lead to prevent the wet driving in. This looks first-class, but does not suit all kinds of architecture.

Welts and Beads.

Before I can go much farther with my work I find it important that the reader should thoroughly understand how to turn a welt, bead, or seam.

These illustrations, Figs. 1,339, 1,340, and 1,341, show the welt in different stages. Fig. 1,339 is the simplest. It is obvious that it is the lead just turned back about 1in. or so. Dormer cheeks are nailed to the jambs in this way. B, Fig. 1,342, shows the welt with a nail. This is for

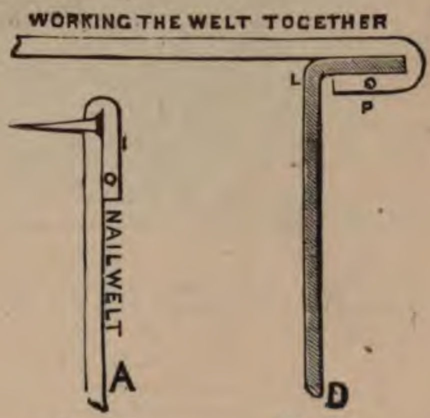


FIG. 1,339. FIG. 1,340.

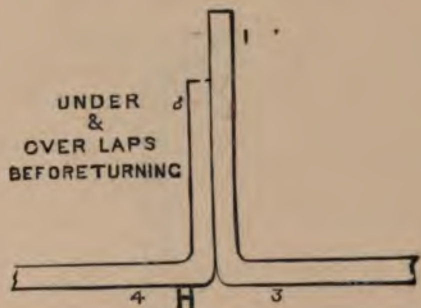


FIG. 1,341.

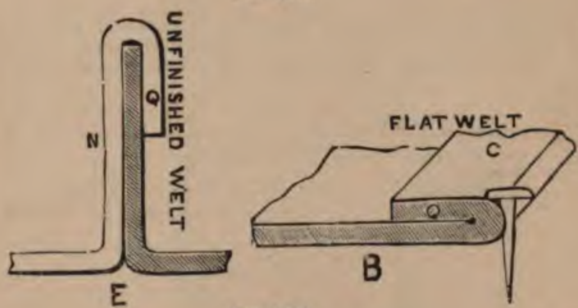


FIG. 1,342.

the wing of flashings when fixed under slates, &c. If nails were fixed through the lead this would give a chance for the wet to get in. The object of turning the welt close is so that the leadwork shall not cock the
It often saves the expense of secret gutters, ill
Fig. 1,314.

H, Fig. 1,341, shows the welt first
H, 3; and Q, N, Fig. 1,342, overlapping
1,343 shows the same with an extra
good work for flats, &c., without
"welting" or seam rolls. D, Fig. 1,34

on for a dormer top; and F, Fig. 1,344, is the shed. Fig. 1,345 is a plain bead, suitable for

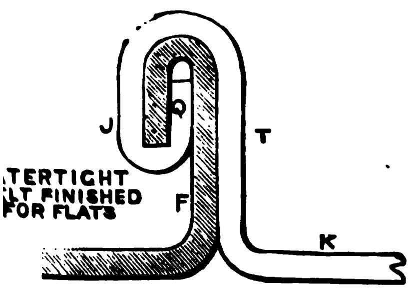


FIG. 1,343.

ds of work. Sometimes this can be worked for tes or tiles, but it must not be fixed to annoy the

Flashings.

These are at times bent with a bending machine, which any zinc-worker in a large way of business will show you, or you can form one out of two pieces of trued-up quartering and a pair of stout hinges in a little time. For another flat welt see also Fig. 1,348, used on spire work, &c., &c.

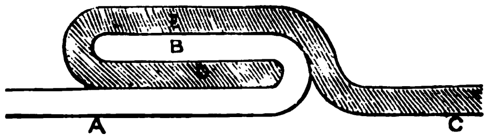


FIG. 1,348.

Fig. 1,349 shows a dormer having a flat top. It will be seen that the cheek is dotted with solder. These dots must

FINISHED DORMER WELT & TURNED

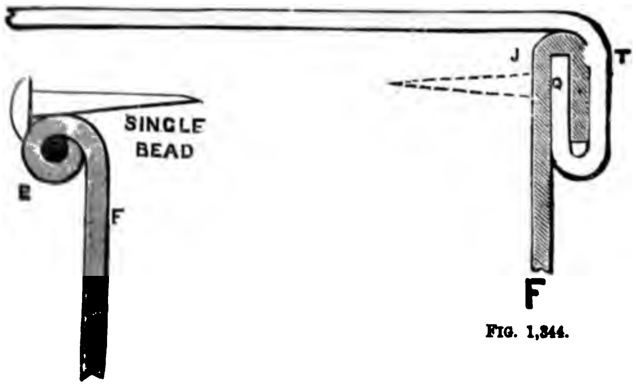


FIG. 1,344.

FIG. 1,345.

the plumber may find it flattened with the Fig. 1,346 is the same welt with an extra turn, 1,347 is a double bead or roll, sometimes formed

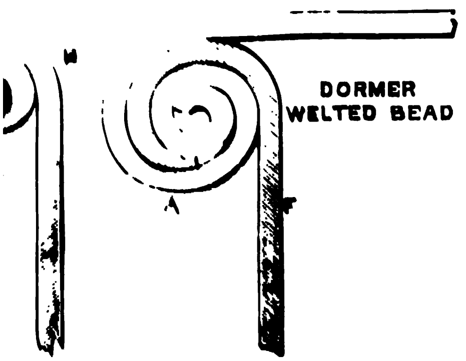


FIG. 1,346. FIG. 1,347.

dormer top, such dormers as may be required to ornamental character. All these welts are generally by hand, with the dresser, wedge and mallet.

be sunk in and wiped flush. The flashing is in one piece; put under the cheek without tacks to hold the cheek at the bottom, and is therefore wrongly done. The cheek on the left is not yet finished. This illustrates the method of forming the welt, as described and shown at D, Fig. 1,340, and F, Fig. 1,344. A, Fig. 1,347, also shows that in reality the cheek hangs on the top welt; but it is quite as well to fix it with a few nails, see J, Fig. 1,344; this holds the cheek up whilst the welt is being turned up. It is, however, necessary to be careful to place the nails high enough, so that the welt shall well cover the nails. Before beginning to work down the corner as at N, Fig. 1,349, that part of the welt should be cut away which will be in the way of working down as at F; cut it right up to the jamb. Then with the mallet and dummy, or bossing stick and dummy, the corner must be worked down as that on the right-hand side. It will be seen that the return lead 7, on the left-hand cheek, is not yet brought round the jamb; this also shows the top of the apron. The top part of this cheek must be brought round the jamb as shown at P, C, and nailed before the top is worked down, and it must also be nailed and then turned as at P, C, N. This welt is described at A, Fig. 1,339; the same should turn over the nails about 1¼in. to 1½in., and as straight as a line and properly trimmed off nice and *straight*. You see now how to finish this kind of dormer, then let us pass to another kind.

Fig. 1,350.—Th... so the cheeks separate

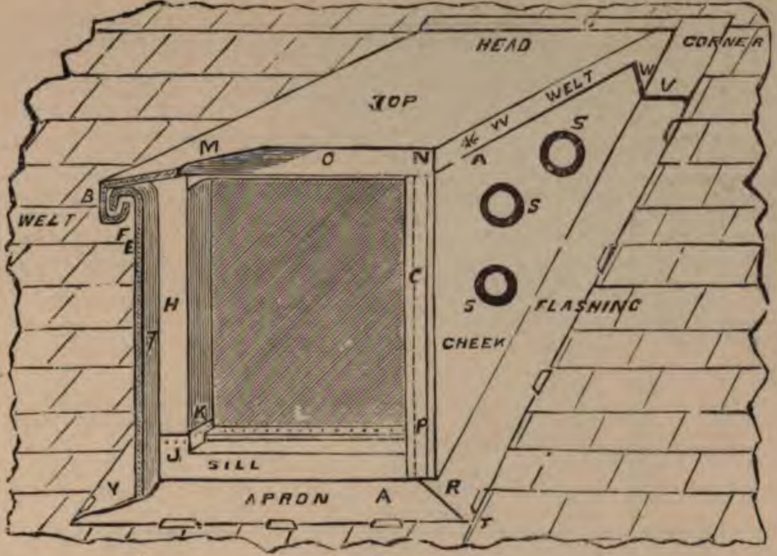


FIG. 1,349.

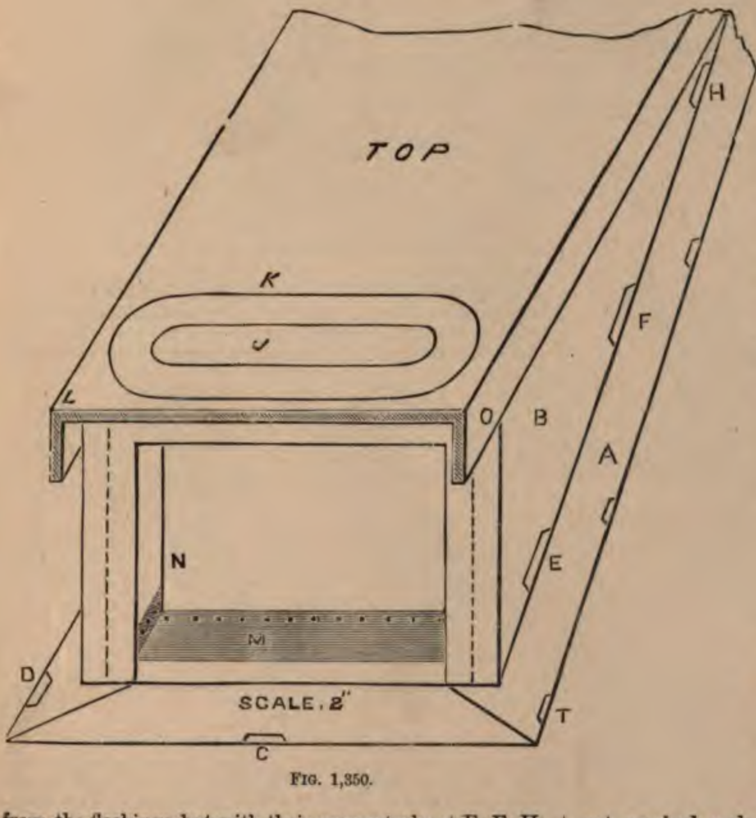


FIG. 1,350.

from the flashings but with their proper tacks at E, F, H. The top is only taken or welted or turned down over the sides—the latter in this case. The front acts as a hood or shelter to the door, and the top is secured down by my method of soldering them as at J, and also sectionally shown in Figs. 1,352 and 1,353. You see first a groove is cut in the top, then a piece of lead, W, Fig. 1,351, or P, Fig. 1, 352, is dressed into same and nailed down as at N, N. This is done before the top is put on. Next the top is put on and this worked down into the groove. Then cut away the top lead as shown at M, M, and shave same together with the fixed lead in bottom. This will, when soldered, hold one to the other, and of course prevent the top rising. J, Fig. 1,350 is the solder, and K, the soiling. Let the solder be nicely done quite flat. The sides or cheeks of the dormer are much more easy to do this way, but take more lead. If they are done in this style you must be careful to have plenty of tacks at the bottom of the cheeks, and well dotted.

Solder Dotting.

(*See* S, S, S, Fig. 1,349.)

This is rather an important part, and care should be taken in doing same. You must not place them indiscreetly, for if you do most likely it will be the cause of the lead buckling in all directions, or ripping itself into long slits. At other times it will only be waste of time and solder to put dots I have often seen dots put on wh not required, and at other times, not on wh South sides require them more than the account of the sun's rays playing upon the ble always use smaller pieces of lead on s

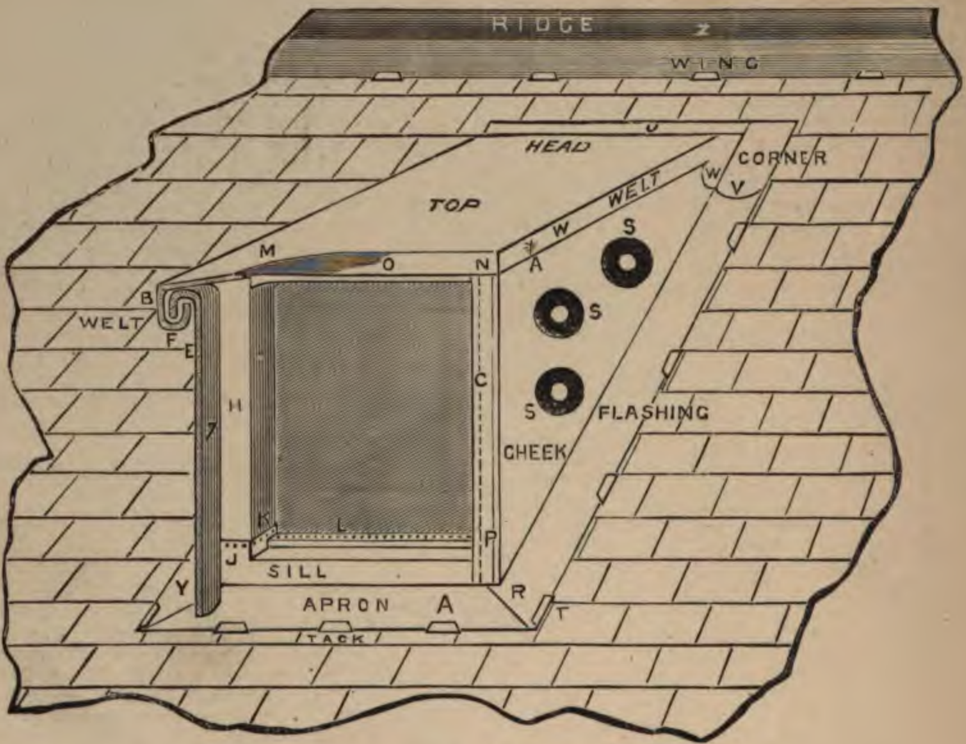
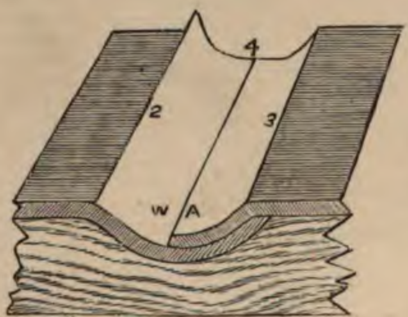


FIG. 1,351.



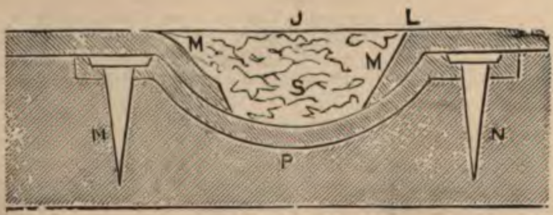


FIG. 1,352.

to what you do on the north sides of buildings, especially on spire work.

The proper way to do this work is to first see the thickness of your boards. See that they are thick enough to drive your nails or screws, the latter is the best, into without going through. If the boards are too thin then block

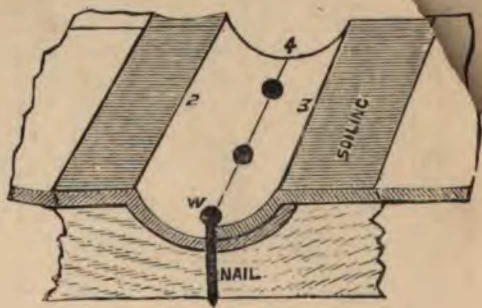


FIG. 1,353.

them at the back by nailing a block at the back of the dot. The usual size of the dots are from 2in. to 2½in., sunk or dished down into the board about ⅜in. The lead is dressed or worked down into this dish, soiled and shaved, then take two small clout nails, and nail the lead there. Next, take two or three good countersunk nails and drive them into

the dish at an angle, or on the splay one way or the other. Do not drive them home, but leave room for the solder to run round the heads. Of course, see that the heads will not stand or project too high above the dish board. Sometimes screws and tinned plates are used. Drill a hole through a penny and tin same. I have given these sizes for the dots; but sometimes you may require to put them on three times this size and strength. The dome of St. Paul's, London, dots are 8in. across and 2in. deep. The soldering is done when upright by splashing it on with a splash stick (in some parts this is known as spitting; the splash stick is then called a spitter), but before you can splash your metal on, you should fix a piece of board about 2in. below the dot to catch the metal. Of course you can do this twenty different ways, with props or otherwise.

Fig. 1,351 is a dormer going up the roof to near about the ridging as at WING, and when such is the case it is better to carry up the TOP lead to the ridge, as the bit of slating is not worth the builder's thought. This figure also illustrates the top worked down and cut, rounded at V, W, and shows how the slating should appear at U, should it be slated. It also illustrates the ridge roll and tacks.

Round Top Dormers.

Round top dormers or ornamental dormers. Fig. 1,354. This is an ornamental dormer, the cheek of which may be as any of those described, either with soakers, or with flashings. The rosette is made from castings, or cut out and bent to suitable shapes, afterwards soldered together. If you cast them, cast them in the flask described in Figs. 15, 16, and 17. Almost any plasterer will supply you with a good centre flower, which will make a first-rate rosette. The difficult part of this dormer to work, is the top. When there is a roll on it you must first set up your under cloak D, turn it down flat back on the lead, then place the lead on top and in its place, then with the chase wedge, dummy mallet, and dresser, work the turn-up over the top of the roll, and nail it there, of course, working the

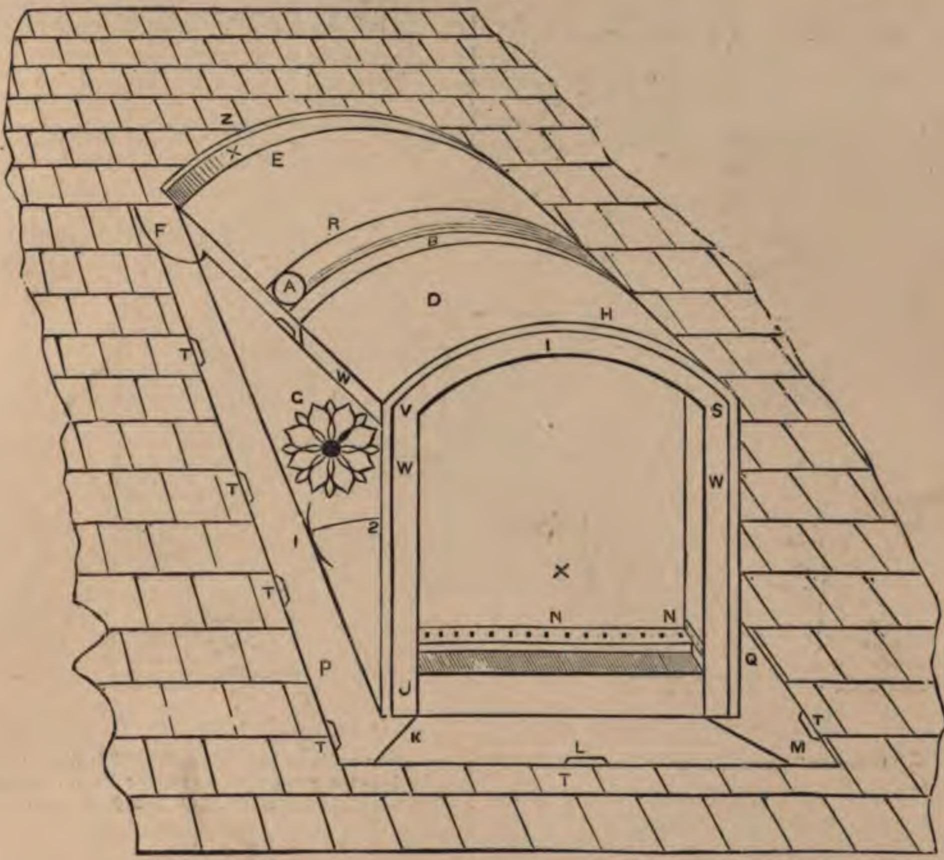


FIG. 1,354.

part over the end of the roll. After this, take the ov-
piece, E, and work this the same way. Sometimes it
be best to work the roll over a piece of roll on the
and take it up and bend the lead the rev
described in working it for the under clo
words, bend the lead to the shape of the
the roll is formed. But I don't like the st

Curb Lead.

This is generally put on as shown at M, Fig. 1,358; and for the laps see A, B, F, Fig. 1,359.

Water Grove.

Fig. 1,359 illustrates a water grove or chase for curb lead work; it is also suitable for gutter flashing going up roofs, as at B, Fig. 1,301. You see the lead in the grove, Fig. 1,359, at A, is the under lap, and extends to the

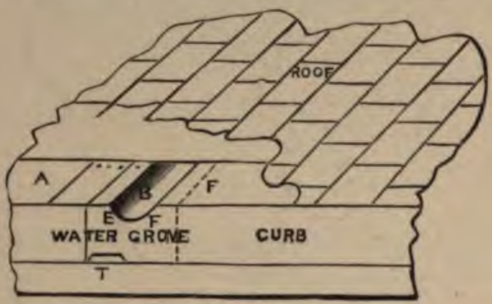


FIG. 1,359.

dotted lines F. E, is the edge of grove, and T, the tack, which should be formed with the bottom edge of the under lap (also called the under cloak), otherwise if a separate tack is employed you will have three thicknesses of lead here and four if a gutter is there. You see, if the water-grove is used, that it is impossible for the wet to get in as it runs down the centre of the grove, or from A, to B, but cannot rise up to F. Of course this is seen a little when the tiling is finished, but not to hurt. If you do not like this, then use a welt, Fig. 1,342, but then the slater or tiler will be apt to growl, as it cocks his slates or tiles.

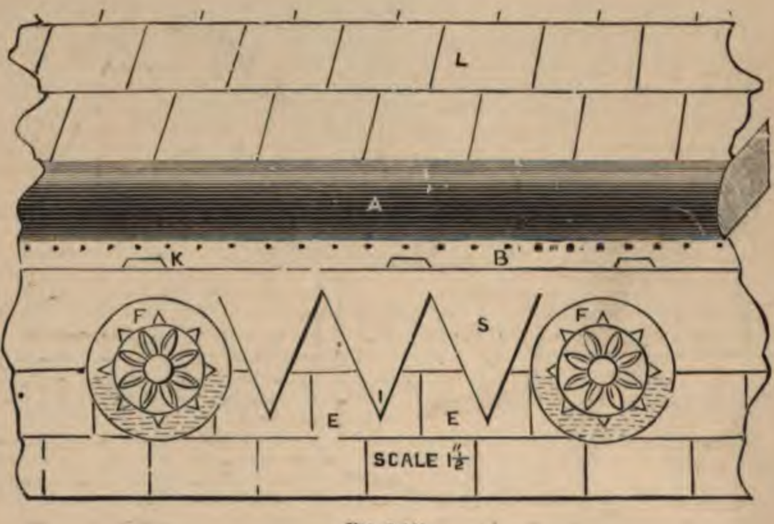


FIG. 1,360.

Also see section of same at S, B, Fig. 1,301, which shows a curb lead over a gutter. Now let us examine Fig. 1,358. Again you see at M, the ends of the slates are in section. These slates come to the edge line of your lead, therefore you must turn up this edge as true as a line. Curb lead is generally cut to 7ft. lengths, and made to go

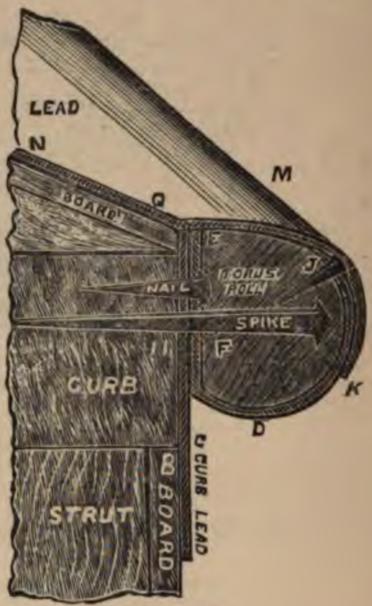


FIG. 1,361.

under the slates 6in., and 6in. allowed to overhang the slates, well secured with tacks and good nails. The lead should be fixed over a ½in. springing, as shown at S, Fig. 1,301, to block up the bottom of the first course of slates. The lead is generally lined down the centre, and set up sharp to the angle of the curb, and then put into its place.

Some curbs have a nosing or roll, as at A, Fig. 1,360. When this is the case you should have the curb lead in two pieces, as shown, CURB LEAD, Fig. 1,361, but not to go under the roll, but nailed as per dotted line B, K, Fig. 1,360; and as a rule the bottom apron or flashing is cut to an ornamental pattern, called scallop work. Fig. 1,362 is a single pattern, cut by first striking the two lines A, B, and from the centres (after they have been equally divided) strike the half circles, then with a carpenter's chisel cut out the square points. Cut this as a pattern, then if you should require a better or more ornamented apron or flashing take Fig. 1,363 and place the saw or jagged pattern under the half round, as per sketch; keep the points A, to

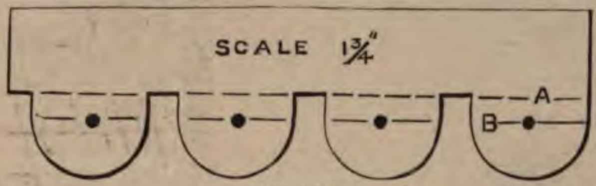


FIG. 1,362.

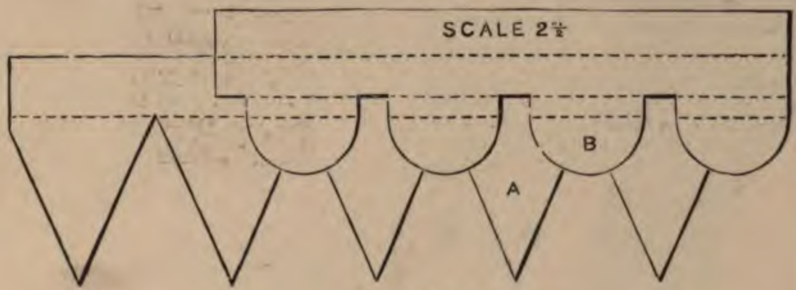


FIG. 1,363.

come between the half circles as shown. Sometimes these flashings or curb leads are ornamented with rosettes, as at F, F, Fig. 1,360. These act as weights to keep the work down; of course they are cast or worked by hand—very simple. In fixing the scallop work you cannot well use tacks, and this is one reason for its use, as it does not rise with the heat of the sun. The top or over cloak has to be bent over the nosing, and worked under as shown at B, Fig. 1,360. You must *well nail* (be sure to do this securely) the scallop work as shown by the dots (of course not through the over cloak), and tack the over cloak down with good strong tacks, not more than 15in. to 18in. apart. Be careful and work the ends and mitres of the nosing sharp and true, as it is an awful job to have anything to do with this after the scaffolding is down. Caution.—Don't forget to use plenty of, say, 1½in. stout nails, and plenty of nail room, say, 1in. to 1½in. at least from the edge of the lead. Sometimes this nosing has a cast cresting stuck on the top of it to answer as a snow guard. It is quite as well to use copper tacks on these nosings, as they are thin and do not appear bulky.

Torus Rolls.

These rolls require the plumber's consideration before he attempts to cover them with lead, for if the lead work is not properly done, when the roof work is being executed, it will most likely be the cause of the re-erection of the scaffolding at a very considerable expense. The best method to cover such rolls is as shown at Fig. 1,364. First decide as to the depth of curb lead to cover the slates or other curb covering, as at B; next cut the under lead for the torus roll as at D. Sometimes it is cut to only go up to about F; at other times it is cut to go up to E. The curb being slated or leaded over, let the curb lead G, and the under lead D, be nailed on, as is in this case 12in. to the curb beam H, as shown at NAIL. Put in plenty of good stout nails. The under lead D, will then be hanging down over the curb lead. Next have the torus roll nailed, spiked, or screwed on to the curb beam, as shown at SPIKE; then turn up the under lead D, tight round the bottom of the torus roll, H, and properly nail the top edge, as shown at J, and rasp off the sharp edge of this lead, as shown at J. After this, fix some tacks to hold down the top lead at K, and proceed to fix the top lead at M, taking care to use plenty of nails at N, and to properly dress down the lead truly and tight over the nose of the torus roll. After this, turn and trim off the tacks.

Sometimes you will be called upon to solder down the lead K, of the torus roll. When such is the case, well sink into the woodwork and along the front edge of the roll, say every 2ft., viz., 12in. of soldering out of every 2ft. run of the roll, and make the soldering strong enough for the work, viz., for a 12in. roll; let the solder be 3½in. wide and 1in. deep. Remember you are not to use nails, as the top lead has only to be soldered to the under lead, especially on the south side of the building.

I may say that this class of work is used on large turrets, spires, and such like places; and where cast sheet lead is used, and (*important*) *properly* cast, this is the very best class of plumbers' roof work for lasting.

If slates or tiles are to be used on the main roof, then a piece of springing should be used under the top lead at or about Q; but if lead is to be used fix the lead as shown with plenty of lap.

The torus roll shown is found at Lothbury Church, City, of which Sir Christopher Wren was the architect, and is doubtless as old as the church itself, yet in a perfect state of repair. The wonder is, how the builders and modern plumbers have managed to leave it there. I se that some of them are looking up the good stout old ca lead from off these City churches lately, or doing what call ringing the changes, and introducing milled lead, lead got out of a frame, as rough or rotten, and porous the sands of Goodwin; in fact, to my knowledge, wit

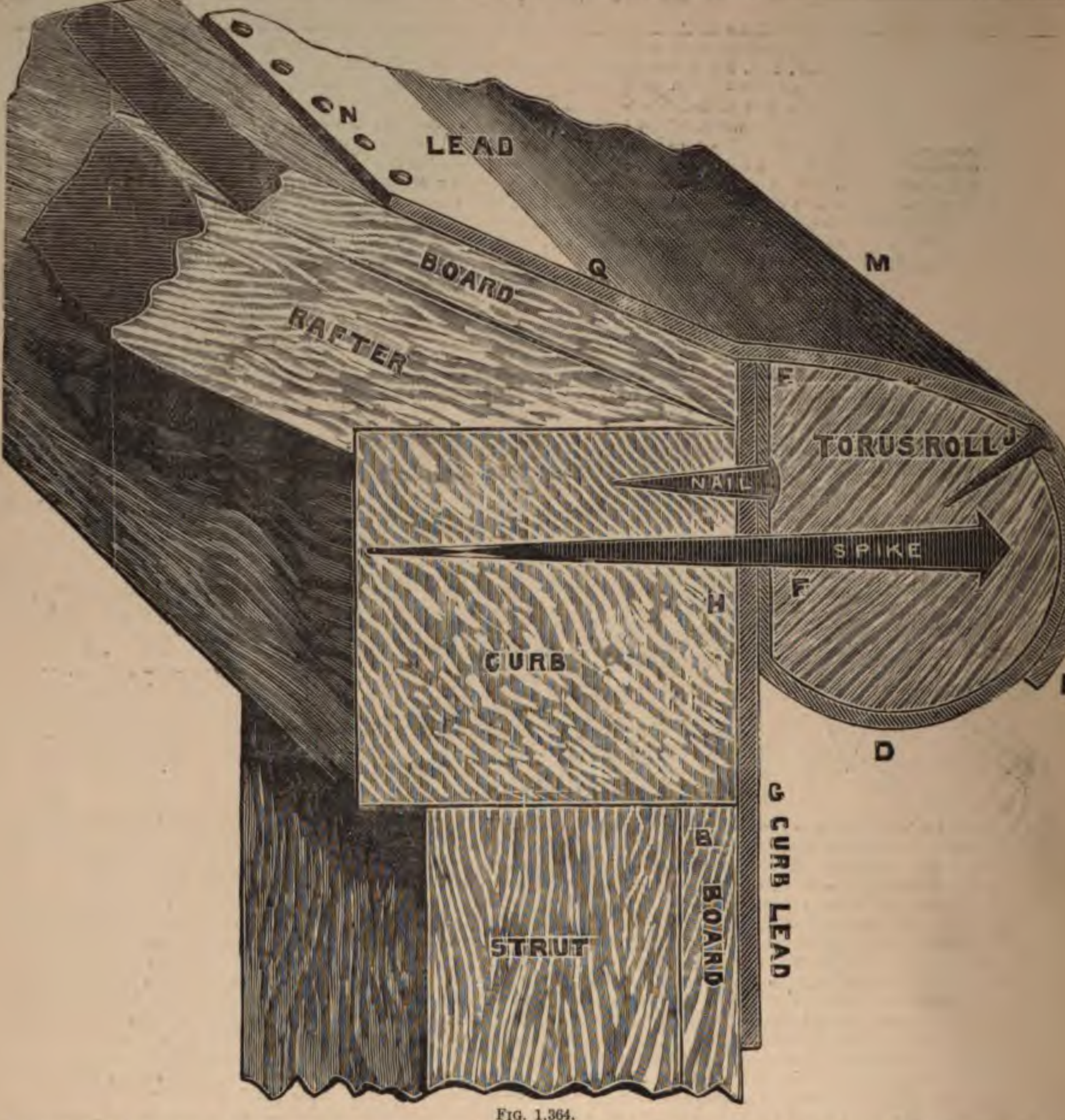


Fig. 1,364.

the last month, a lot of labourers (not even plumbers' labourers) that never before saw a bit of cast lead, nor frame, are employed to do lead casting, which is to replace some of the good old work on our City churches. This I consider to be the greatest disgrace I ever witnessed in the plumbing trade, and I say shame to the architect and builder that allow such lead work to be done, or to be gulled by those who try to run down good cast lead for milled, because they are incapable to cast lead *tough*, and as it should be, viz., thoroughly smooth, free from lumps, cracks, and other defects too much for the duffer to manage. It has just come to my knowledge that a clerk and a brass finisher are busily engaged in instructing labourers in the art of sheet lead casting, these men not even having seen a frame before. Doubtless the work will be mulled over, but I pity the payees in, say, twenty years to come.

Lanterns.

Lanterns are made to almost every conceivable shape; but for showing the method of covering the principal part—the base or curb—I have selected an oblong. At A, Fig. 1,365, is a lead flat over a staircase; and B, is the lead turned up about five inches against curb or base for lantern. Of course, when the rolls come butt up against the curb, they must be worked down in the ordinary way, to be explained hereafter. T, are the tacks for holding down the flashings. These flashings play an important part about the lantern, inasmuch as they act as gutters to catch the condensed water which is formed by the difference of the

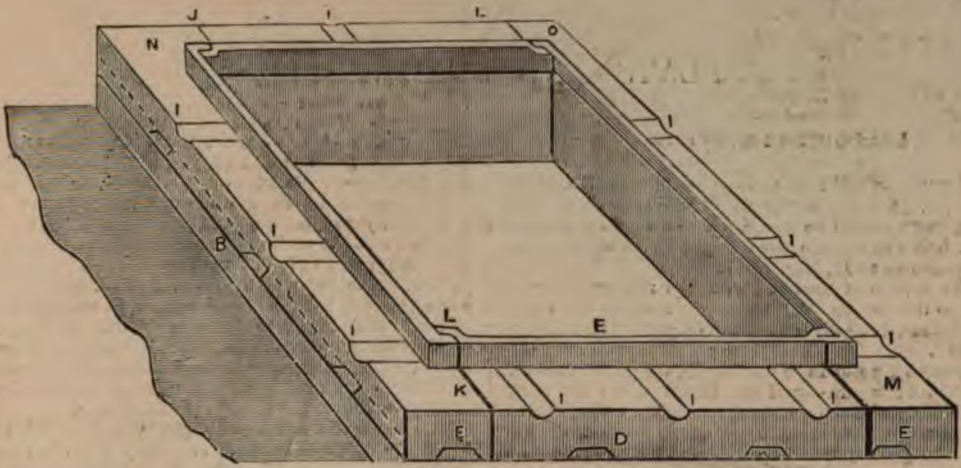


FIG. 1,365.

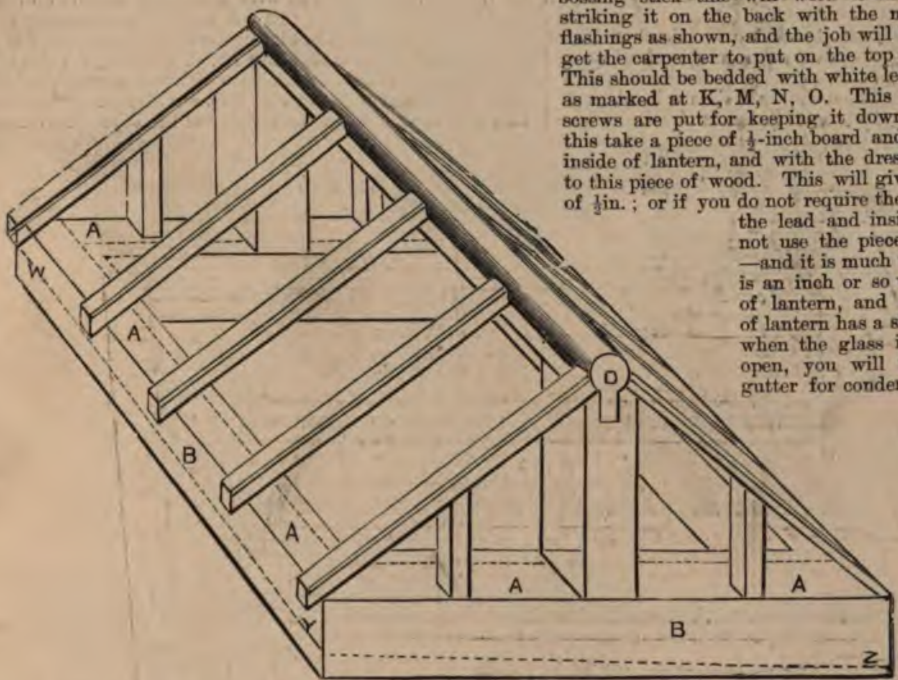


FIG. 1,366.

inside and outside atmospheric gases. This, as before stated, is of the utmost importance, though very simply effected. First, have the water groves as shown at I. They should be cut down at least ¾in. and 1½in. wide; then fix your lead about 1in. over the inside face of the curb, and stick a copper nail in it here and there just to hold it in its place, and solder over the heads with a copper bit. If you place a single welt, A, Fig. 1,339, under the joints, as at K, M, J, L, it will be all that is required. Next, with the mallet, or mallet and bossing stick, work the lead down into the water groves. If you have a round bossing stick this will work it down true, that is, by striking it on the back with the mallet. Trim off the flashings as shown, and the job will be a good one. Next, get the carpenter to put on the top or lantern, Fig. 1,366. This should be bedded with white lead at the four corners, as marked at K, M, N, O. This is where the nails or screws are put for keeping it down on the curb. After this take a piece of ½-inch board and place it on the lead inside of lantern, and with the dresser, dress up the lead to this piece of wood. This will give you a stand-up edge of ½in.; or if you do not require the space of ½in. between the lead and inside of lantern, then do not use the piece of wood. Sometimes—and it is much the best plan—the curb is an inch or so wider than the bottom of lantern, and sometimes the bottom of lantern has a sill on same. Generally, when the glass is in a frame made to open, you will then require the lead gutter for condensation water, to be on the sill in lieu of the curb, and in some cases, both when the lead is on the sill, it is usual to cut the bottom of the frame for the water grove. Fig. 1,366 should have lead flashings to come up, and also form a gutter and be nailed to the dotted lines, as marked at A, A. This lead should be worked over the sides of the sill B, B, and brought over the flashing, E, E, Fig. 1,365, but the tacks for same must be nailed on the sill, B, Fig. 1,366, and take care not to stop the way of water groves, I, Fig. 1,365. The roll should be covered with lead to come over the glass about 1in., and fixed with lead headed nails, or as best you can. (See Ridge Rolls.) Of course, when you bring the flashings up to form a gutter, as in Fig. 1,366, the curb, Fig. 1,365, does not always require the turn-up lead, F, but the flashing on B, Fig. 1,366, covers the lead B, Fig. 1,365.

FLATS AND SEAM ROLLS.

Lead Gutters and Flats.

All lead gutters should be at least of 6lb. to 7lb. sheet lead, and 7lb. to 10lb. would be a far better job. The angles or corners should be bossed up, and the drips worked down 2in. into a receptacle such as a rain water head or cesspool, as shown at H, Fig. 1,367.

H, is the bottom of cesspool, with the rain water pipe soldered into the bottom. This cesspool receives the water from the gutters, &c. N, is the head of gutter, and G, the base or tread.

When gutters are put in to receive the water from slates, it is usual to fix the turn-up of the lead 9in. up the roof, or from the bottom of the gutter up under the slates, and to provide and fix a feather-edge springing 4½in. from the bottom of the gutter, to tilt the bottom of the first row of slates.

Gutters for Lead Flats.

The gutter G, Fig. 1,367, should have at least a 2in. stand-up edge, E, which is turned down into a rebate, and nailed there with 1¼in. clout nails, as shown at F. The turn-up at N, and also against the wall, should be at least 6in. to 8in., with bossed-up corners at the head.

to be originally 12in. wide, then, if we make it 3ft. wide, this alteration brings the bays right. If, however, this is not practicable, perhaps the plumber can put the bays in in two lengths, having another drip in the centre. Another reason why the bays should not be 12ft. is that this size does not suit the cutting out of the lead, as the sheet, being 30ft. long, will only cut two, and leave a piece 5ft. or 6ft. square. Another way to get over this difficulty is to put a bay at the head of the others, crosswise, and bring the head of the bays A, B, C, to finish, or "butt up" against the head bay. Of course this head bay must not exceed the length of the others, and should have one side turned up against the brickwork, the other being worked down over the drip and over the head part of the rolls.

The width of a flat is easily got over. First it is necessary to see the width of sheets. Say they are 7ft. sheets, and that the width of flat is 33ft. Here are twelve bays, and the workman can make his lead come in very well with 1½in. or preferably 2in. rolls for the under cloak. It should be turned up 2½in. The over cloak will require 8in. for working and trimming; this will leave a good margin, and allow the bays to be 2ft. 9in. in the clear. Say the flat is 33ft. in width, the sheet being 7ft. The latter, divided into halves, gives 3ft. 6in., out of which 9in. are required for rolls, which leaves 2ft. 9in. If 33ft. are divided by 2ft. 9in., this goes twelve times the number of the bays. But there

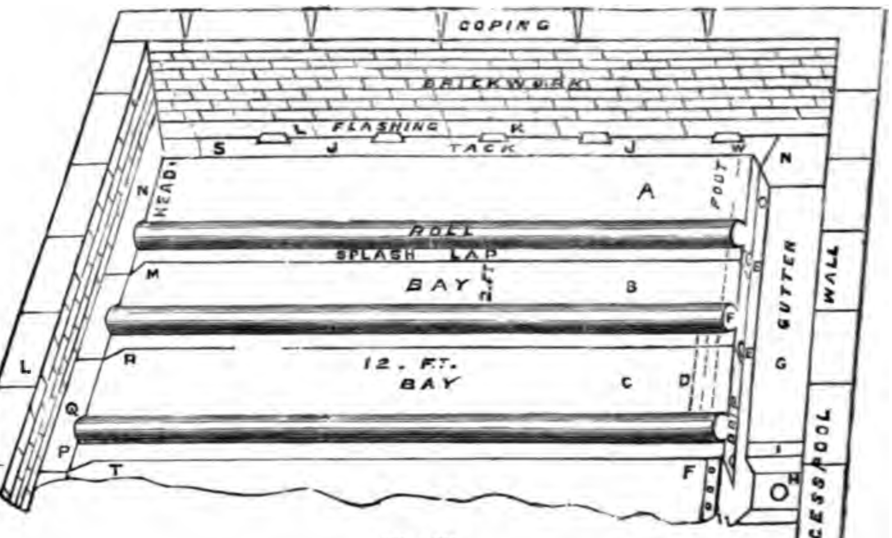


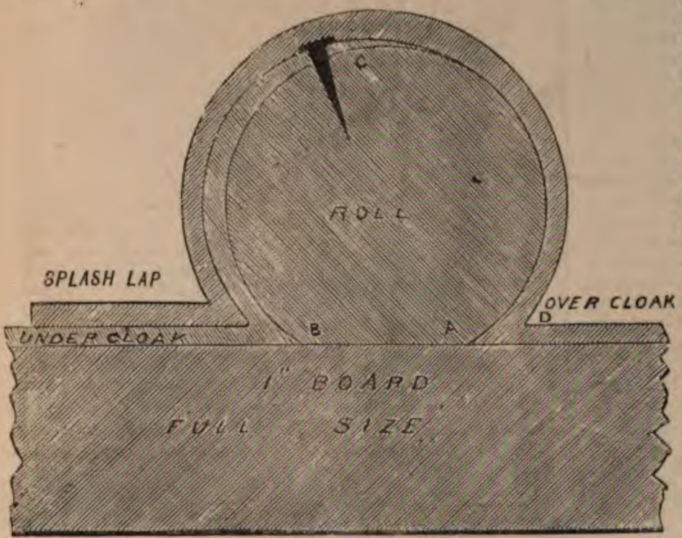
FIG. 1,367.

Lead Flats Arranging.

If Fig. 1,367 be examined, it will be seen that there are A, B, C, each having a 2in. roll with splash lap. ...e this flat to be 12ft. from the head to the ... too long for a bay if exposed to the sun; ...ugh, then. We can therefore try and shorten ...rider gutter, G. If we suppose the gutter

is something else yet to allow for; this is the base of the roll, which is generally 1in.; therefore the lead has turned up another inch less, so that 12in. will be gai... the twelve bays, and also 3in. on each bay turn-up ... the wall, making in all 18in. Then, instead of ... the bays 2ft. 9in., they may be turned up 2ft ... cuts to waste, but it cannot be very well ... using a smaller roll and less turn-up

practicable to work a bay less. This is often done, to a sacrifice of good work; but should not be done upon any account. If the plumber happens to be short of an inch either at the head or side of the bays, against walls, the difficulty may be got over by fixing a feather-edged board against the wall. It is not a bad plan to divide the flat into about the width suitable for the lead, and then have the rolls bored for the nails and cut to the exact lengths, but not fixed. They can then be shifted an inch or so either way, and then nailed down by the plumber.



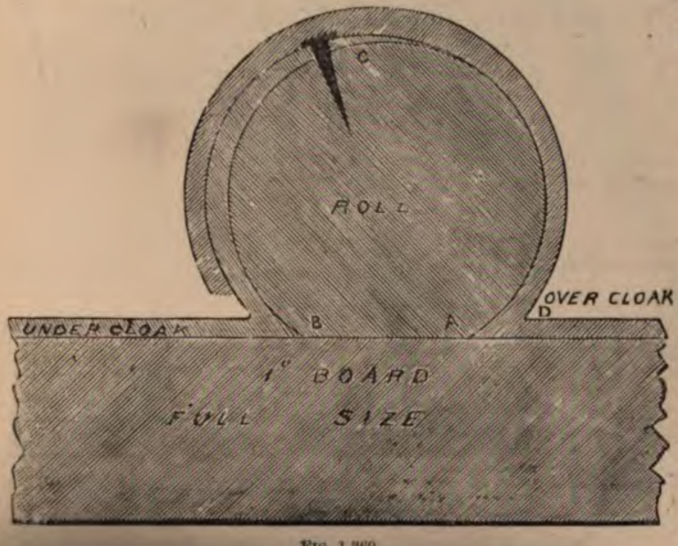


FIG. 1,369.

... the rolls. It is important that ... for unless the shape ... to,

shows the under cloak well worked into the angle (but not so as to cut the lead in two, you can work it sharp without this), and going up to the top of the roll as at C, where it is rasped off so as not to leave a ridge or mark in the top of the over cloak. The method of nailing the under cloak to the roll at C, is also shown in the figure, and the method of working the over cloak over the under cloak, and forming the splash lap as at F. This splash lap is of great use, as it prevents the rain from rebounding and getting to the nails, *or over the roll*, especially in rough weather; it also answers as a kind of girder or stay to keep the over cloak from springing up in hot weather; in fact, its use cannot be dispensed with *in good work*. Fig. 1,369 is the roll turned without the splash lap, which is duffers' work. See Fig. 1,376 for the evil effects.

Having everything complete, the workman first unrolls the first bay, and measures the turn-up against the wall. Should the fall of the gutter run in a line with the joints of the brickwork, the lower end of the stand-up lead should be cut, so that it will run parallel with the brickwork joints. This saves a step in the flashing, as from S, to N, Fig. 1,367. Now snap your chalk line to this. Next measure for the turn-up at the head of the bay against wall at N, P, &c. *Notice.*—This is an over cloak bay, and, therefore, last to fix. Next, with the rule or bevel, the angle of the walls should be taken, and to this next snap the turn-up line on the head of the bay. Most likely this line will be out of square, but don't trouble about that, but see that the next line snapped (that is, the under cloak line) is exactly square with the head line. This will bring all the other bays true and square. Having marked out this bay, before going further it is necessary to see if there is length enough; if not, an inch must be taken off the head. I always like to have 2½in., and near about where the tack comes, at the under

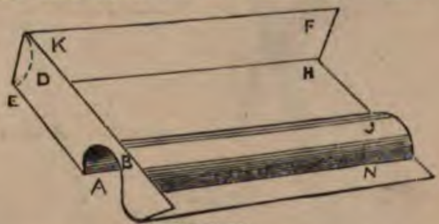


FIG. 1,370.

cloak end of roll, 3in. to form a tack, as shown at E, E. This tack holds the over cloak from springing away. When the lead has been marked all out (6in. up against wall and 2in. for under cloak), it should be pulled up against a piece of quartering, and set in. Next the corner for wall should be bossed or worked up square, as shown at E, Fig. 1,370. Afterwards the corner for the roll should be bossed up, as shown. It will be seen that the roll is round; therefore, the lead should also be worked up round as at A, but only the 2in. high. This should be done by working it with the tools, and then offering a short piece of roll, Fig. 1,374, up against the work until the plumber gets it to the shape required. In this case it is not necessary to come past B. Sometimes it will be necessary for you to work your bays with two over cloaks, a thing not recommended, but if necessity drives for it then work this over cloak as shown at Fig. 1,371. The use for this is when two plumbers are at work on one roof working towards each other.

Raking Out Joints.

The next thing is to put this bay into its place, but before this is done the joint of the brickwork should be well raked out at least 1½in. for receiving the flashing. It is important that this is done before the lead is laid, as the grit in the mortar getting under the lead soon works holes into the lead.

Joint Rakers.

This is done with a joint raker made to the shape of a timber-dog, &c., or, in other words, it is a piece of steel about 18in. long, and pointed, and then turned round to a right angle, or square. The part which is to rake the joint should be hardened, and not too thick to go into the joint. Its length is about 3in., leaving 15in. for the handle. All this length of handle is required for some joints. Some get the joint out with the tang of a large file bent round. These make good joint-hooks. Others get them out with a hammer and chisel by placing the point of the thin chisel against the joint, and striking the chisel's side close to the point, or, say, an inch or so away. When the mortar is very hard it has to be cut out with the hammer and chisel. For stone or gauged brickwork it is cut by those who cut the bricks, &c. There is nearly always a bother about who is to do this job. It really belongs to the bricklayer or mason.

Having the bay now in its place, take the roll, and if you require the ends to stand up square to the flat, of course have them cut square; but if you should feel a little indisposed for work, cut the end on the splay as at D, Fig. 1,381. When nailing down the rolls, bore the holes in the roll, say, every 12in. apart; then take some 4in. and nail the roll No. 1 down closely, knocking the tight up against the side of the under cloak, as show K, Fig. 1,372.

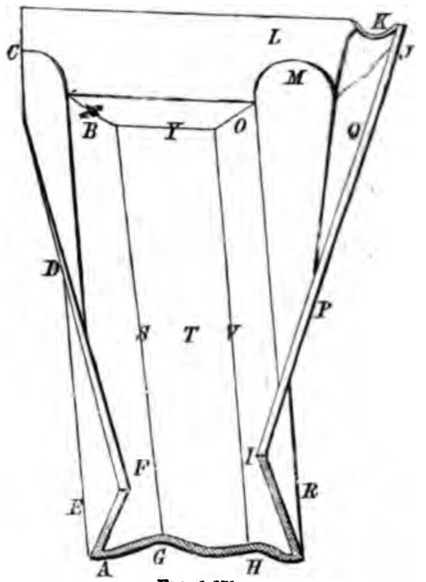


FIG. 1,371.

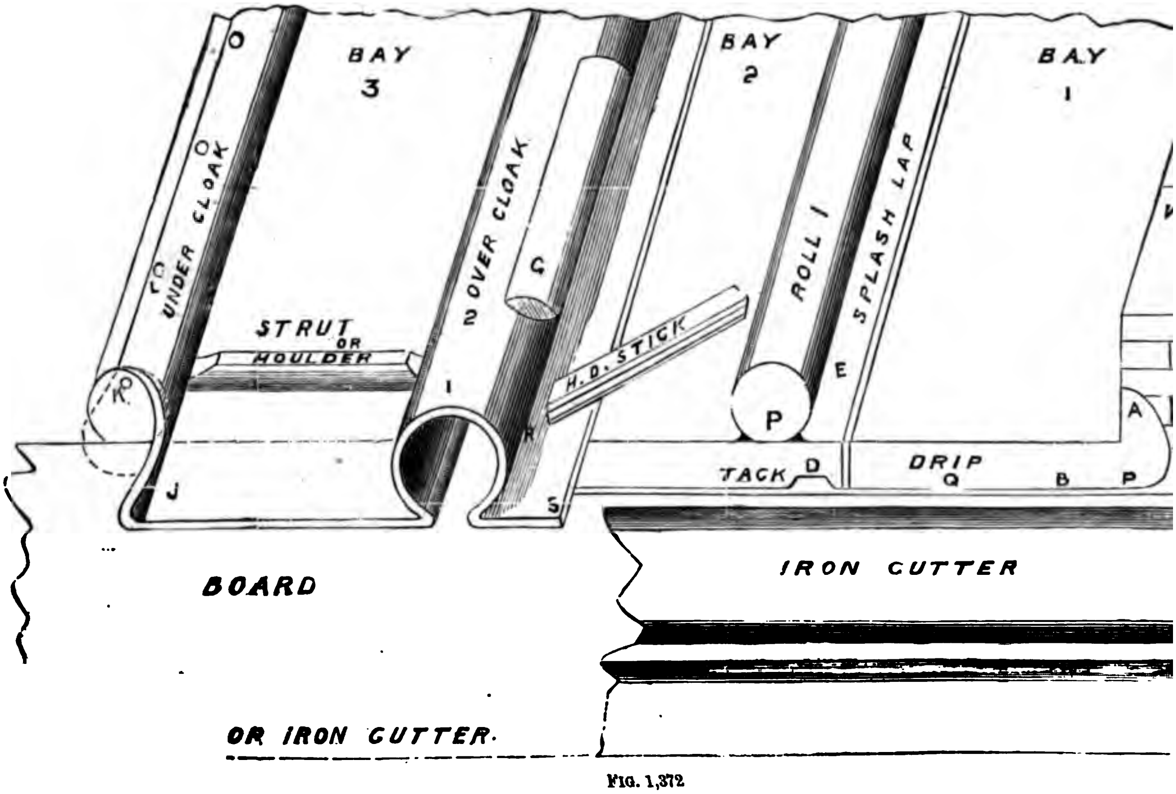


FIG. 1,372

Next go to the head of the bay and put down the corner against the wall, as at B, Fig. 1,373; and go along the angle of the turn-up and lay this down also. Stick a nail

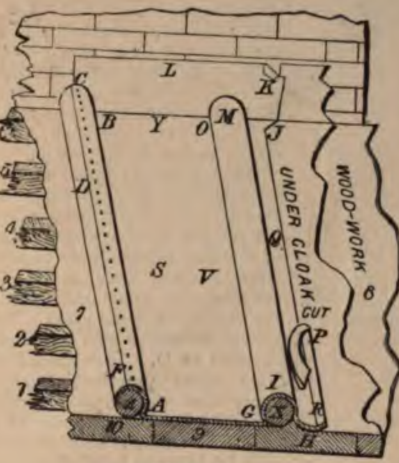


FIG. 1,373.

into the side and into the brickwork, as at L, Fig. 1,373, or turn a tack as shown at K, to keep it down and from springing, and work down the head of the roll as at J, K, M.

Next work the drip down, as at A, C, B, Fig. 1,372, as you would a gutter or chimney-drip, as follows:—Knock the flap or drip part of the lead down first, as at B; then work the lead from B, towards P, and from P, to C. At the same time work the lead a little, not too much, down from about A, towards C, so as not to strain any part too much; in fact, if you have any idea of straining it, work some more from about Q, towards B, P, C, and the corner is down. Next take the roll under cloak, as at K, knock the roll well up against the lead before nailing it, as is very well shown at A, Z, Fig. 1,373. Next nail the roll down and dress the lead down into the angle; next knock the top edge over the roll, as at F, D, C, also as at L, Fig. 1,372, from head to foot; then work the top or head of the bay down and over the end of the roll, to look like that at the head of bay or about the point M, Fig. 1,367. This looks well down (also see D, Fig. 1,368). Next take the rasp and rasp off the sharp edge of the lead, as shown at C, Fig. 1,368, and nail it every 9in., as also shown in the same figure, also on roll at L, Fig. 1,372. Next work the under cloak round the end of the first roll, as at K, in the dotted lines, Fig. 1,372. Next is the over cloak bay. This is set out somewhat different to the last.

In the first place, we have no brick wall for the sides to rest against. We must now have sufficient stuff for an over cloak. Look at B, J, Fig. 1,370. Here you see the thing required. F, K, is the under cloak, to be turned up 2in. or so, and worked (hollowed for the roll) as per dotted lines E, D, similar to the first bay; and the distance from E, to A, the width of bay, must be the same as before. But the over cloak is, of course, longer. Then, again, it should be worked as near to the shape as possible (without spending unnecessary time), as shown at A, B, J, N (but keep the corners rounded). This is done, as before described, by working the lead to the shape, and often offering a short piece of roll to get the right shape and height. Never get too high, or to exceed the height by a quarter of an inch.

Having worked the ends to the necessary shape, put the bay into its place as before, and then nail down the roll No. 2, as shown at UNDER CLOAK, Fig. 1,372. Suppose that the first bay is laid, and roll No. 1 finished as a pattern, and that you are about bay No. 3. First lay or work down the head of the under cloak, viz., as shown at R, Fig. 1,367. Next with your dresser and mallet, come down the roll, setting the lead in, and nail or tack the leadwork round the end K, and knock down the drip at J. Next see that the over cloak angle of the lead is well down on the boards from head to foot. Now get a strut, or holder, made to fit in the bottom of the rolls as shown at holder, Fig. 1,372. This is best made a little shorter, say ½in., and wedged tightly there. This holds the lead down firmly to the boards, and prevents it springing up. See that the under cloak edge is rasped off. Next place a piece of quartering along the over cloak angle of the bay; then you and your mate push over the over cloak as well as you can. Keep the quartering there, you still kneeling upon it, and with a short piece of roll, Fig. 1,374, or as shown in its place at

FIG. 1,374.

G, Fig. 1,372, which is say 18in. long, with the arrises taken off, and the large hammer (a plumber's large hammer should weigh at least 2½lb.), knock the lead into a hollow, as shown at R, the labourer holding the edge of the over cloak from springing up, as shown at H, D, STICK. With this tool go from within 9in. of the head to the foot, after which take the dull hornbeam dresser and go from top to bottom (of course not too near the top) until you have worked it down. Next place the plate (a piece of flat steel 9in. long, 3in. wide, or a point of a saw) under the over cloak, and take the dull chase-wedges and points and mallets and work down the over cloak at the head of the roll, in much about the same way as you would a drip. Work it down by first bending down the turn-up P, Fig. 1,367, or J, K, Fig. 1,373, and stretch it on the top edge, from about Q, Fig. 1,367, so as to allow the lead to go well down into the angle, and complete the same to look as shown at M, R, P, T. Remember this, let the lead be thicker here than any other part of the bay, as this is where tinkers spoil the lead.

Next let us work the end of the roll I, Fig. 1,372. First see that the strut is within about 9in. of the end of the lead, or, say, 6in. from the end of the drip, and wedged firmly up. Get on your knees and pull up the end of the over cloak from S, to R. Next take a mallet of handy size, say 5in. long and 2½in. over at the largest end. You then begin working away as quickly as you can all round the top part of the roll, not touching the edge, until you have got it down, say, 1in. equally in every part, holding the short dummy under the lead to prevent puckering, but don't get hammering the dummy, to thin your lead like gold leaf. Keep on at this until it is nearly down. This will cause the molecules of lead to fly away in all directions. The quicker you work this the better it goes down. It must be trimmed off straight, and the tack left on the under cloak and then turned and trimmed off as shown at D. The way to trim off the lead is shown at P, Fig. 1,373, and D, Fig. 1,372, is how the end should appear when finished.

When trimming off the splash lap, cut the top end as at J, Fig. 1,373, a little on the splay, say 2in. from the angle towards the roll. Also cut the turn-up on the splay or out of the upright, the top part leaning over as shown at M,

is the object. I have covered several churches where I have been engaged to re-cast the lead. I also did the greater portion of the National Gallery for Messrs. Jackson and Shaw, the well-known builders and contractors, and also the Victoria Tower at the Houses of Parliament, being foreman of plumbers to its celebrated builder, viz., John Jay; and the diagram now before you, Fig. 1,377, is engraved from an accurate drawing of one part of a job done by myself many years ago at St. Martin's-in-the-Fields, London, and is a masterpiece of lead laying. The engraving is too simple to require any further comment.

All places like our Royal parish church above referred to, should receive great care that the work be done in not too large pieces, with plenty of tacks and other fixings.

Seam Rolls.

There is not much seam roll work done nowadays. I should not be doing my duty to let this be an excuse for my omitting to give my reader directions to do such work.

Flat Seams.

Seams, as you know, are two pieces of lead put together as at Fig. 1,348; and although some may ridicule the idea of putting two bays together like this, nevertheless such work is to be found; and has stood the test for hundreds of years. But remember with such seams the roof or flat requires a good fall; say one in four or five: although I have seen this class of work with very little fall, one in twenty, and yet sound.

Stand-up Single Seams.

Fig. 1,378 plainly shows an old method of making the joints of bays waterproof, and although the modern workman may laugh at the idea, it is one which is simple and answers the purpose. Of course the edge of the under cloak can be held down by nailing tacks on the boards and

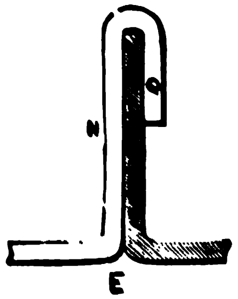


Fig. 1,378.

bringing them up with a turn over exactly as shown at N, Q, care being taken to let the tack flush into the floor board. There are many ways to work the head or foot of this seam, which we will leave to the judgment of the reader.

Stand-up Double Turned Seam.

Fig. 1,379 is much the same as Fig. 1,378, except that in this Fig. 1,379 the under cloak has an extra turn at Q. Here is a real good bay joint and a seam that will with-

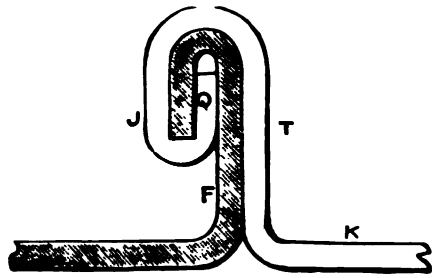


Fig. 1,379.

stand any storm or even a fireman's hose if the water be allowed to run away, and, considering the excellent drawing you have of this, it would be waste of time to say more about it.

Seam Roll.

The seam roll is at times turned hollow with only one roll, but what I prefer to make is that illustrated at Fig. 1,380, and is nothing much more than Fig. 1,379 with an extra turn or so, and this is all that need be said about it.

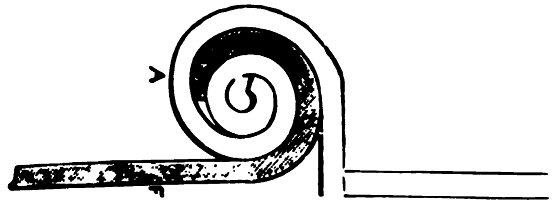


Fig. 1,380.

It is used for cast lead jobs on church or other roofs requiring first-class work. Any quantity of tacks can be used with such, and should be used freely.

I should say that the rolls can be turned with a dresser and mallet, or you can get a blacksmith to make a pair of tongs with the jaws about 6in. long, to assist in turning over the rolls.

The head of the roll, viz. (the head of the bay when against a wall, &c.) should be on the under, and part of the over cloak cut away when working over the roll. Also cut all you don't require away for the end of the roll, but as a rule the ends are left simply knocked or bent over the curb or springing without a lot of finishing off.

Generally seam rolls finish on the top of a roof, as at Y, Fig. 1,377. Hints for the roll ends:—The first or second you do, you had better fill the roll up with some pieces of lead rolled up, or by cutting a few blocks the size of hole, about ½in. long, and filling up the hole with the same, called "stuffing" or "cramming"; but where this kind of work is required you scarcely ever want the ends worked down, which is for allowing expansion or contraction more freely than close worked rolls.

HIPS AND RIDGES.

(*Also see Figs.* 1,303, 1,310, 1,311, *and all the other Figures having Hips and Ridges.*)

Hips and Ridging.

Fig. 1,381 illustrates the end of a roof, having the hips B, E and D, H covered with lead. It also shows the ridge R, covered with lead, and the end of hips intersecting the ridge roll, but the whole covered with the finial N.

The method of covering these parts is as follows :—First you want to know the shape of the rolls and how they are fixed. They should be as round as possible, with about ¾in. placed flat base, and at least 2in. rolls. If from 20ft. to 40ft. high they should be larger, say 6in. for 80ft. in height. The best plan is to nail the rolls on the apex of roof, so that the bottom will come just flush with the top of the slates as shown at A, Fig. 1,388. By referring to Fig. 1,391, you will see the roll fixed with holdfasts, called ridge roll spikes, as at F. The one end is driven into the roll, the other into the woodwork H. The ends are generally cut to a vertical line.

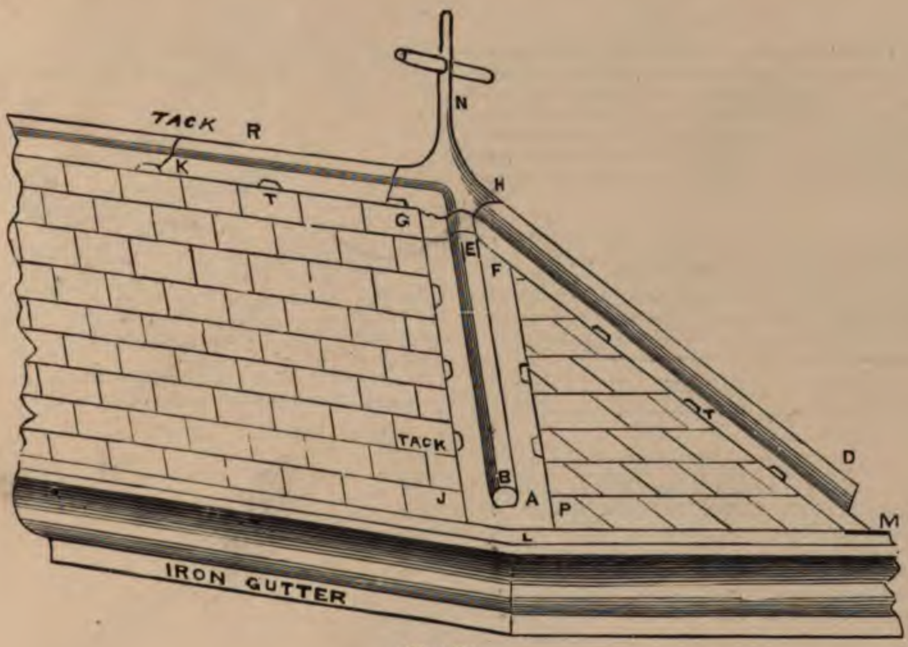


FIG. 1,381.

Gauges.

Having the rolls right, make a gauge (see Fig. 1,382) as follows :—Take a strap of lead 2in. wide, about the length to go over roll, and allow 7in. on each side to go over the slates. Place this strap over and round the roll, as though you were about to cover same, as shown at the end of the section, Fig. 1,389. Bend the lead close into the angles, and mark it on each side as shown at F, E. Then measure off 6in. on each side, as at H, J, Fig. 1,382, for the wings. Then take the lead off and straighten it out. D, is where you marked in the angles. This is the distance for your lead to go round roll. With the snips put the four nicks in, as at F, D. Next divide these to marks as at B, and put these two nicks in as shown. This is for your centre line. Next measure off the nicks or notches from D, to J, 6in.,

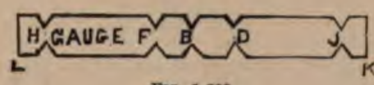


FIG. 1,382.

and put the two nicks in as shown. Also measure off 6in. on the other side from F, to H. This is your gauge. The best way to cut out this lead is crossways of the sheet—

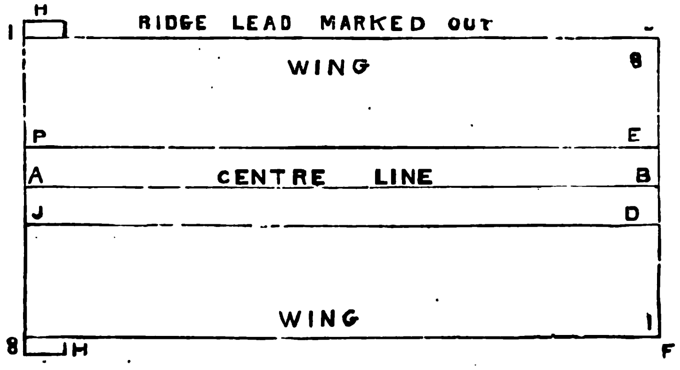


FIG. 1,383.

that is, in about 7ft. lengths. They should be cut at least ¾in. wider for trimming off, and for the tacks as at TACK, Fig. 1,390. The Fig. 1,383 shows the method of lining out same. A, B is the centre line, which should be scribed or scratched on with a straight-edge and round-pointed bradawl. D, E the angle lines. If you have a great quantity of these to mark out, it is best to have a gauge

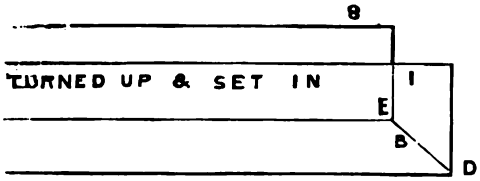


FIG. 1,384.

made with a piece of quartering just the width, and between the lines D, E, H, H, Fig. 1,383, and K, Fig. 1,384. Then you can do with two gauge-marks. If so, you need not use the chalk line at all, but scribe all the lines as shown at E, D, Fig. 1,383, the centre line B, then D, E, 1,8,G. If you do not wish to trim the edges off, after they are put on the rolls, you may then scribe the two outside lines 1,8,

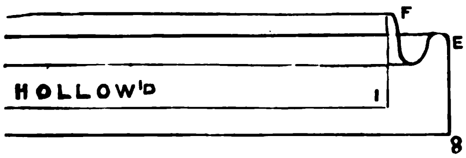


FIG. 1,385.

and cut straps off, leaving about 3in. to form the tacks as at H, Fig. 1,383, and B, Fig. 1,387. Then take the gauge, and scratch the lines D, E, Fig. 1,383. Keep the gauge still and kneel upon it, and pull both sides up as at Fig. 1,384. Set these angles in sharp, and square the sides true as shown. This is done by dressing them up with the dresser. Next turn the tacks on one side, and turn the length on its edges, as shown at Fig. 1,385. Take the short piece of roll, Fig. 1,386, placing this roll on the back of the

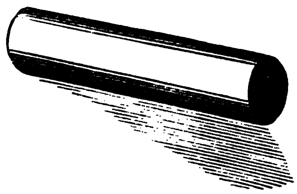


FIG. 1,386.

lead as at E, Fig. 1,385. Strike it with the large hammer to sink it from one end to the other, as at Fig. 1,385. Then

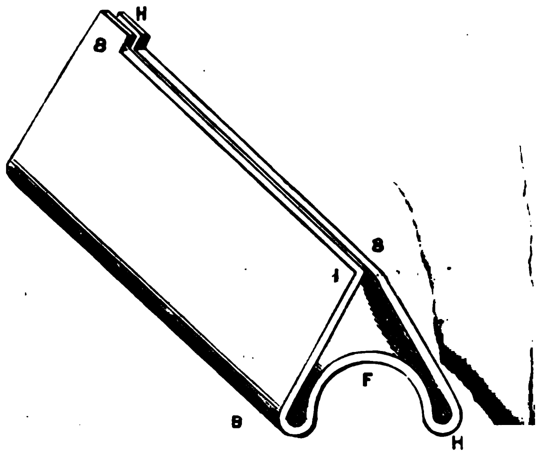


FIG. 1,387.

dress up the angles true and turn it over, as at Fig. 1,387, and push over the wings as shown at H, 8,1,8.

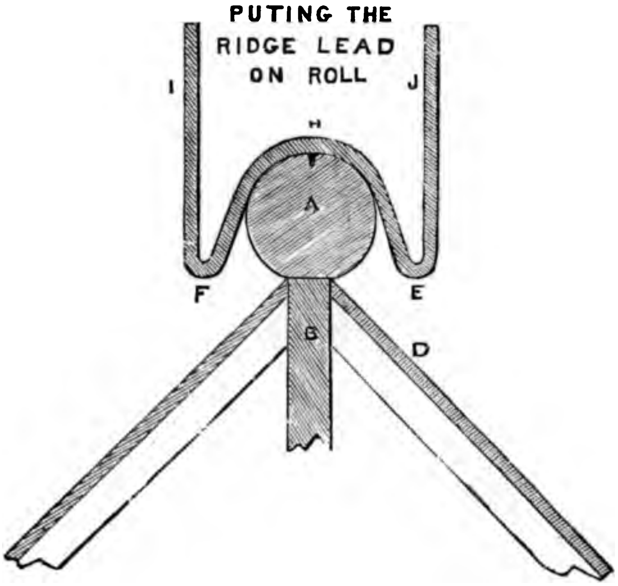


FIG. 1,388.

Tacks.

You have now seen how to cut out, work up, and set up the lead for hips and ridges. Next, let us fix the same, but before we can do this it will be necessary to describe the tacks. (See TACK, Fig. 1,381, and TACK, Fig. 1,390, and also Fig. 1,389, which shows the method of fixing them to the woodwork, B.) These tacks are cut about 2in. longer than the wings—namely, 8in. long, and from 2½in. to 3in. wide, and should be of stout lead. They are fixed about 18in. apart, and turned up tight to clip the lead wing as shown at I, J, but be sure not to break your slates in turning. A good plan is to push up your "plate" between the slates and lead to hammer upon during the turning of the tack, or a stout piece of zinc will answer the purpose. (See plate.) If you look at Fig. 1,389 carefully, you will see that if the lead is put properly round the roll and well tacked up, that it cannot move. The ends of these tacks should be cut on the splay and the corners cut off, as shown

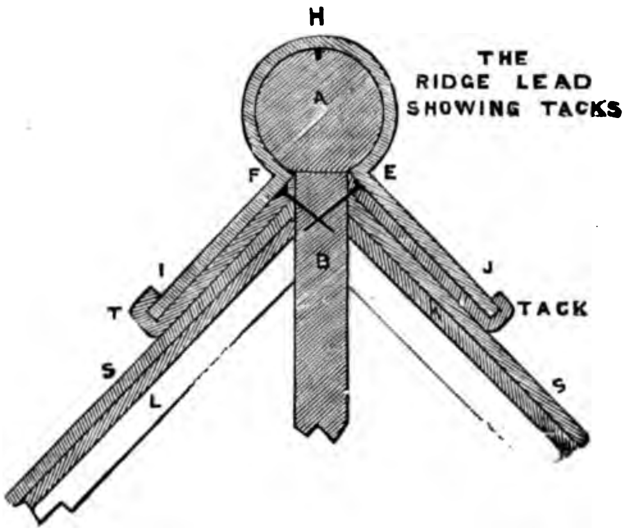


FIG. 1,389.

at TACK, Fig. 1,390. Having them all right, let us next see about putting a piece of lead on. But first you should, if required, have a good duck ladder up the slates to walk upon. This prevents the breaking of the slates, and will be safer for the workmen.

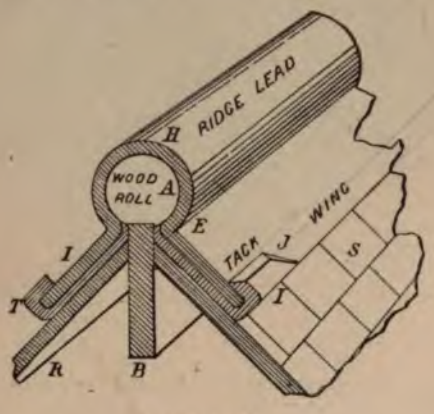


FIG. 1,390.

Duck Ladder.

This is made by nailing some short pieces of wood, say slating batten, up a good scaffold or an inch board, say every 10in. apart. Here you have something to walk up. You must fix it as best you can, often by tying a scaffold-cord to the ladder, then driving some large nails into the ridge; or you can nail a strap of lead to the roll and also to the ladder—the strap will answer as one of the tacks.

Fixing Hips and Ridges.

Having made your run, and your tacks fixed every 18in. or so apart, and to suit the lengths, take the piece of lead, as at Fig. 1,385, and look out for the centre line, which is to be fixed in the centre of the roll, put a black-lead pencil line (see dot on top of the roll, Fig. 1,389), all along roll-centre, and now fix your centre line to it. You have it in its place, as at Fig. 1,388, but it don't fit there. Make it as follows:—The mate holding one end on roll (let the mate catch hold about 3in. from the end), you take the other, and you lift your end up, say, 8in. off the roll, then bang it down two or three times. Your end is now nearly down; let your mate do likewise; but do not hold it half-way down the length of the lead, catch hold 3in. from the end. Finally put the centre of your lead on the centre line of roll, as shown at H, Fig. 1,388; let your mate also do this. Next see if you have lap enough, 4in. or so; and now stick a nail or two in the under cloak to prevent it moving; next open your hands both of you, and both at once pressing equally on each wing, push it down upon the slates; the angles will then go home. Next, with a nice boxwood dresser and mallet, or hammer, chase or tuck the angle tight in on each side, your mate keeping the same from springing. This is now so far done (see Fig. 1,389); next turn up your tacks, as shown at T, J, Fig. 1,390. You have now your bottom length on; next nail it thoroughly round the top or under cloak, especially if it is a steep-pitched roof. In some cases you want a copper tack, a strip of copper, 1½in. to 2in. wide, not too thick, and nailed on centre of roll to hold up the bottom part of the lead, especially for such as those going up the angles of a curb roof. You have, say, the bottom length now fixed ready for the end to be worked down, which you do as you did the ends of roofs on flats. You will now require a plate for placing under the parts of lead dented so that you can dress the dents out, although the wood or brickwork at back may be rough or hollow. It is also used to place between the under cloak and over cloak of drip corners or ends of rolls whilst they are being worked down; touch the top side of the plate over, as the lead slips better on this smooth and hard surface.

Working down Roll Ends.

If required, take your plate and work down the end of the roll, place the plate under the same and with the small mallet set to and work the end down with quick and light taps. Work it very even and smooth, sometimes using the dummy to prevent it puckering. Keep away from the arris of the roll until it is down. Practice away at this in the shop, &c., as follows:—Take a piece of lead about 18in. wide, turned up to the shape, having four nails stuck in the outer edges and into the floor. Work away in your spare time, say an hour in the evening. Practice any time you can get a chance. You can always get a piece of new lead for a piece of old for this purpose. Practice marking and cutting out on stiff brown paper, or with lines on the floor. Having worked down the roll pretty near but roughly, take and smooth it up as well as you can with the small boxwood dresser, and leave the arrises square and to the shape of the end of the roll, as illustrated at A, D, Fig. 1,381. Having put this length on take another length, place it over the last, and give it 4in. to 5in. lap, and so on up the wall. This end piece should be worked up, say, 2in., to go against the ridge or wall, and turn it into the joint, or as shown at Y, Fig. 1,315. Of course, you want to cut this to the shape, and bend it up before you attempt to fix it.

Intersection, or Top Pieces.

These are simply cut to the angles, by first taking the angles with the bevel, and the capping piece worked over as a finish. (See Fig. 1,381, &c.)

Capping Piece.

This is put on as shown at N, Fig. 1,310, &c. Its shape may be obtained by carefully marking out your lead and working it to near about the right shape, after which put it on the roll and bump it down with easy dabs on the roll, and also partially work the lead round the parts of the hips. Next, take it off the roll or lift up the capping end, and with your mallet and dummy, work it to as near the shape as you can; then put it into its place and again dab it down. This is sometimes called horseing, bumping, or dabbing the work down according to the country, but generally we say horseing when we make the work on blocks, sometimes called blocking, such as blocking up heads, &c. When you have it nearly down, take the dull chase wedges and tools and work it down and trim it off, as shown at Fig. 1,310, also turn the tack as shown at G, Fig. 1,381. The Fig. 1,381 shows you how to finish these rolls on a parapet, or other gutter. Fig. 1,391 illustrates a ridge roll fixed with spikes sharped at both ends, which keep the [illegible] off the roof. I cannot say that I

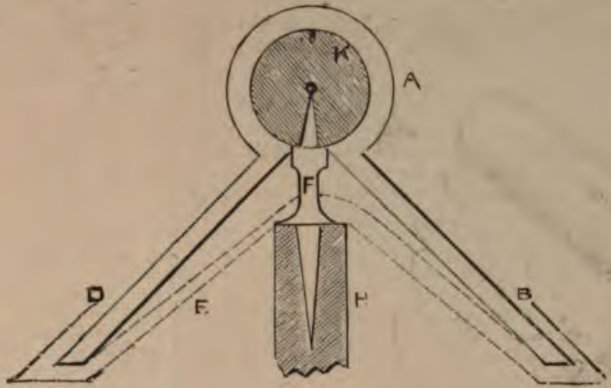


FIG. 1,391.

like this old method of fixing the rolls. The idea is to get more under hold of the roll which is made quite round. Generally the tacks go right from one side to the other, as shown by the dotted lines E, and nailed on H.

Fig. 1,390 illustrates the ridge roll lead as it should appear upon the slates finished.

See also Figs. 1,303, 1,310, 1,311 and 1,312, &c.

VALLEYS.

Valleys may be seen at nearly all the dormers such as at Figs. 1,330, 1,336, &c. The lengths of lead should be 7ft. off the width of sheet, and never exceed 8ft. or 9ft. in length, as the sun plays upon them.

for a man to walk up without treading on the edges of the slates. From the angle at M, to the bottom of springing, should be at least 5in. each side, and from the top of the springing at O, to the top edge of the lead, another 5in., so

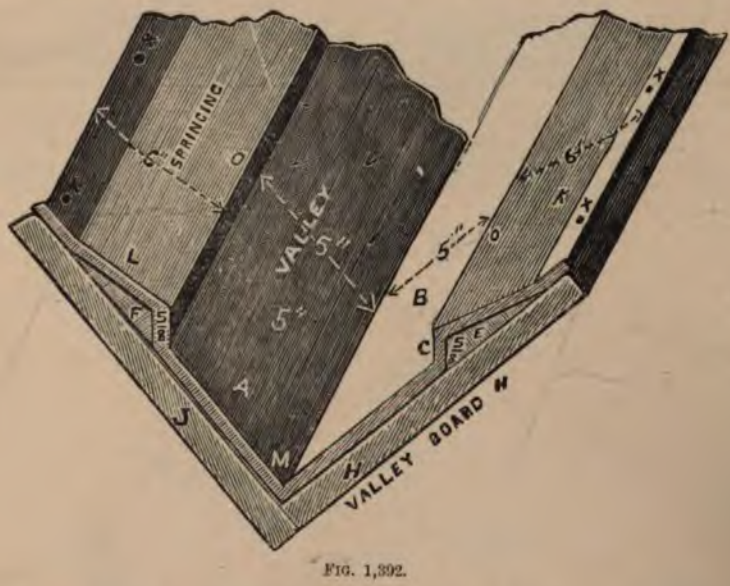


FIG. 1,392.

Fig. 1,392 shows the valley and springing, E, F, with the lead work, A, B, L, K, M, set in sharp and finished; it also shows the nailing, as at X, X, X, X. X. The general width for valleys should be at least wide enough

that the required width of lead should be 20 some places you may require 6in. under the former is the least I would allow for a go... Sometimes they run much wider.

There are many different methods of laying lead in valleys. One way is to simply set one line down the centre of the lead, and set it up to about the angle of the valley. Put it in its place, and with a piece of quartering placed just under the springing, as at C, Fig. 1,392, pull up the lead again and then press it back, and so bend the lead into its place, after which take the hammer and dresser and set it in middling sharp, at the same time flattening the top of the lead just at the arris of the springing. If you do it this way, do one side at a time and nail it. Do not spoil it by making it too sharp. The proper way is to first line out the lead, marking the centre line first as shown at M, N, Fig. 1,393, then set up the side as at K, L, then lay your lead into the gauge or mould, Fig. 1,394, which is made the exact size or width of the valley between springing and angle M, Fig. 1,392, and with two pieces of springing nailed parallel upon the scaffold, then place the turned-up lead, Fig. 1,393, in same, and placing a piece of board about the thickness of the springing down in the lead, kneel upon same, and turn it (the lead) over the springing and dress over the arrises to the shape of template, gauge, or mould. This is easy and makes good of the lead go far enough to trim off in a line with the bottom edge of the slates or tiles, and if in Gothic dormer work, let the same stick out true with the slates or tiles,

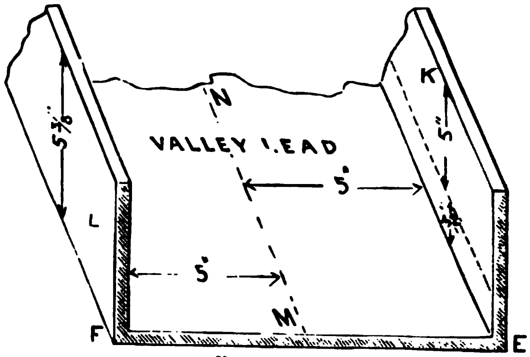


Fig. 1,393.

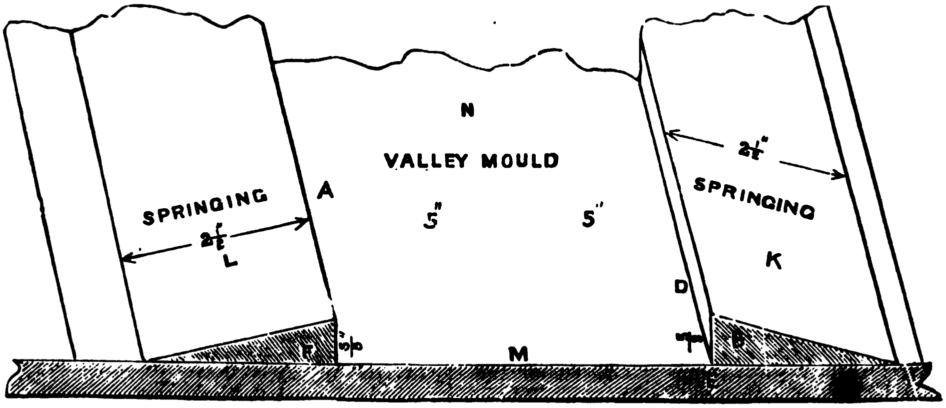


Fig. 1,394.

work, and the lead looks as that in Fig. 1,395. After this, set it up in the centre to the angle of valley boards and drop it into its place. See that the lead goes up 5in. because in this work the slates or tiles generally—or should—project about 2½in. over the dormer cheek, and the end of the valley would look odd if worked down as shown at

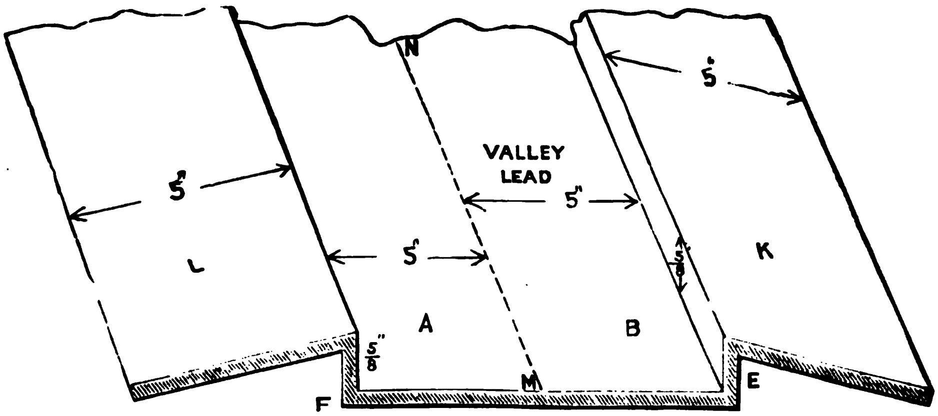


Fig. 1,395.

above the top of the springing, and that the over cloak *([illegible]st piece put in) goes* well over the under cloak, *at F, top of dormer, Fig.* 1,336. Let the bottom A, in the same figure. Of course, all other kinds of architectural dormers should have the ends of the valleys worked down as shown at K, Fig. 1,336.

LOUVRE AND OTHER VENTILATORS, TURRETS, SPIRES, DOMES, ETC.

Louvre Ventilators, Fig. 1,396.

In this figure you will see a lot of lead work, which will be both instructive and useful. This is a louvre ventilator, which is, as the name implies, used at the Louvre Palace, France, and is suitable for places like over a kitchen, laundry, theatre, or other place requiring such an apparatus. This one was entirely covered with 8lbs. lead by myself some years ago. It was done as follows:—First the hip lead A, was put on (described under the heading, Hips and Ridges), then the flashing C, B, D, Z, which goes up and over the sill or curb. This should be properly worked up the stud as shown by the nails at 2. Next the studs are lined and the lead is properly worked into the grooves for the louvre boards, as at P. This lead comes down the inside and over the turn-up of the flashing, as at E, S; also over the tops of the hip rolls. It also goes up under the lintel lead, as shown at 3. Next fix the lintel lead like you did the curb lead, and nail it on top of curb above the arris. Take this lintel lead $\frac{1}{4}$in. below the bottom of lintel and turn a bead, as at Fig. 1,345. Let the turn of the bead be turned outwards, as the water running down this flies over the louvre boards with a kind of spring or bound, especially when it is raining very fast. If you like, you can convert this bead into a kind of gutter by increasing its size, as at A, Fig. 1,347.

Next, line or cover and fix the louvre board. This is all you have to do:—Have them all fitted, but be careful to have the proper allowance made for the extra length and thickness after they are lined with lead. They are fixed with lead or copper wedges driven into or between the grooves and boards at the top. Next cover the top, mark or set it out as shown, or as you like.

Sometimes you can convert lanterns into first-rate ventilators, so as to answer both purposes. For instance, if Fig. 1,366 be made, say, 6in. larger all round than the base Fig. 1,365, and kept up, say, 6in. or so, which may be done by placing two beams across the curb, the ends of which support the lantern, or by raising the lantern any other way and fixing weather-boards on B, Fig. 1,366—of course, with flashings to cover same.

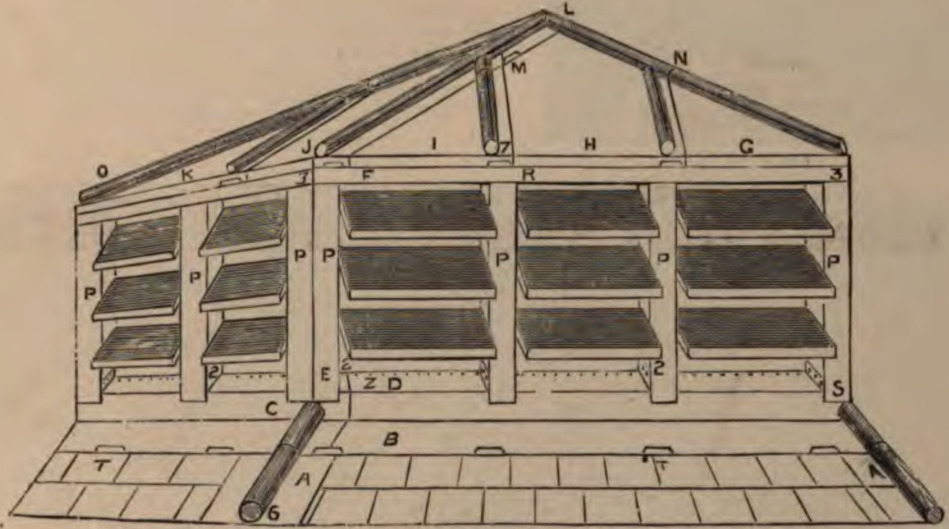


Fig. 1,396.

Ventilator Pipes and Pitched Roof Intersections.

The reader will thus see how to make and cover a square ventilator, but there is another which is often fixed upon the roofs. This is the round one, or air pipe, and I cannot pass this unnoticed, as it is an excellent problem in cutting out sheet lead; and how many plumbers are there out of a dozen to be found capable of working same geometrically? More than this, how many foremen or clerks of works are there out of a hundred who can do it? Look back on Fig. 1,301; here we have a ventilator goin[illegible] through the side of a roof. This shows that the hole the apron must be of a different shape to that of a m[illegible] circle. Now, suppose your ventilator to be, say, 18in. 2ft. in diameter, your apron should be, say, 6in. larger th[illegible] this all round, and in some cases this should be more the top, in order to go well under the slates. Say [illegible] roof is pitched at an angle, or to that making the [illegible]

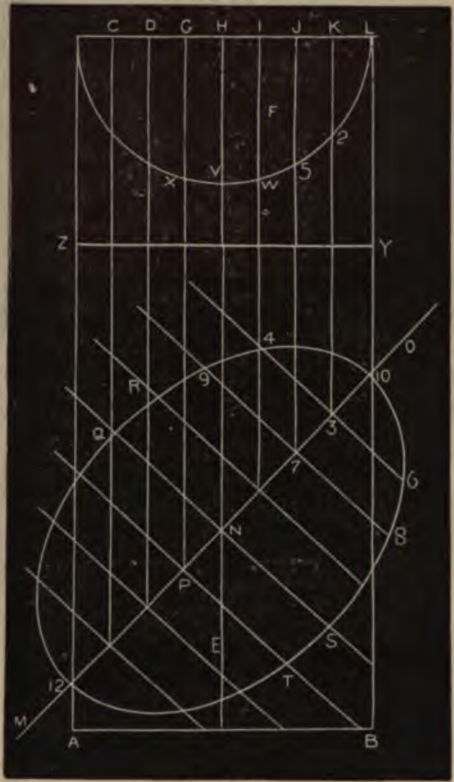


FIG. 1,397.

described at Y, O and M, Z, Fig. 1,397; here you have M, O for your roof line, and A, B, Y, Z the side of the ventilator or air pipe. You have here a pipe or cylinder cut at an angle or obliquely, and by so cutting it you at once obtain an ellipse, and a round or circle cut in the apron cannot be expected to fit the cylinder at this angle. This being the fact, we will, just for the sake of practice, go geometrically to work and cut the lead to fit the ventilator exactly. First, say the size of ventilator is to be 2ft. over, and the apron or flashings round this to be 6in. all round, this makes 3ft. one way; but this size piece of lead is no use to us. We want a much larger piece. Open a sheet or a piece of lead large enough, and first set out the size of the ventilator, as shown at A, B, Z, Y, Fig. 1,397, then with your bevel take the pitch of the roof, M, O, and the perpendicular line of ventilator, Y. Mark this on your lead—that is, draw the angle or roof line, M, O. Next, you must have a half plan, F, of the ventilator. On this plan draw the line C, L, which must be divided into any number of equal parts, as at C, D, G, H, I, J, K, L; then draw the lines C, D, G, H, I, J, K parallel to the sides of the cylinder to cut the roof line M, O, as at N, P, &c. Next you want the square lines Q, S, &c. You see these lines are square to the roof line, and cutting the points or ends of the lines C, D, G, H, I, J, K at the roof line P, N, &c; next on these square lines you obtain the shape required by measuring off the plan the distance between the point on line K to the half circle point 2; this will be your distance on square line from 3 to 4, and from 3 to 6. Then, again measure the distance from point J to point 5; measure or set this distance also on the square line 7 to 8, and also from point 7 to point 9. Go all round the half plan in this way, and then from the point 10 to 6, 8, and from the point 10 to 4, 9, R, Q, &c., draw the curve line 10, 6, 8, S, T, 12, Q, R, &c., and this will be the exact ellipse or

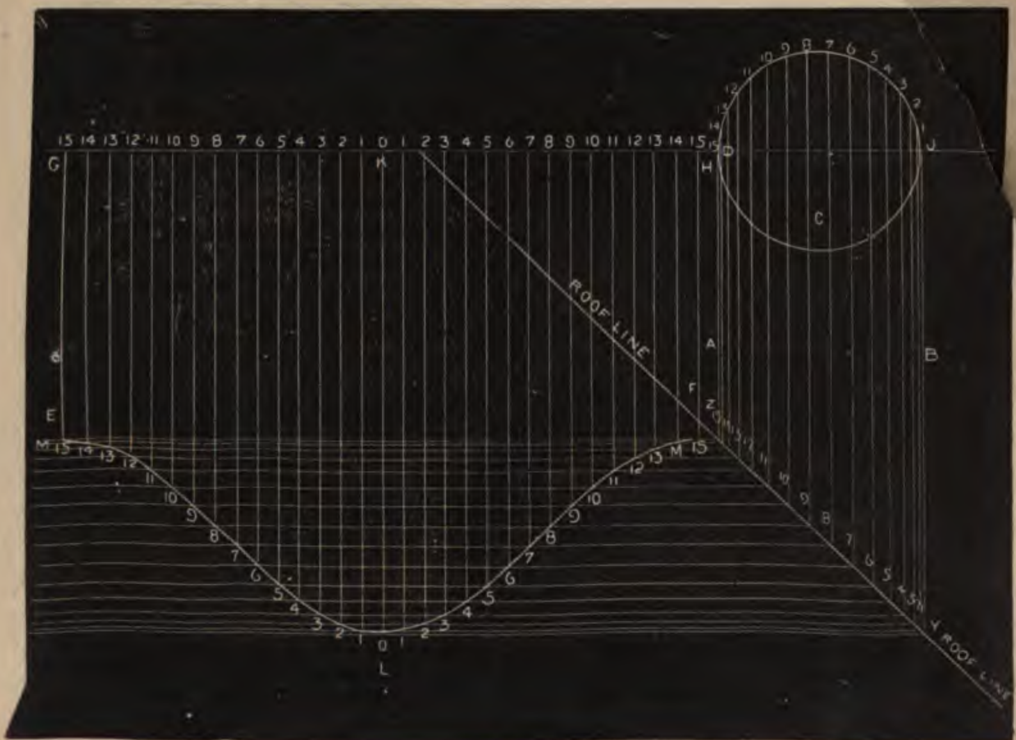


FIG. 1,398.

fit for the piece of lead or apron wherein the ventilator stands. Now if you require a turn-up of, say, 3in. or 4in., you must go round the inside of the ellipse, and if 6in. are required to lay on the slate, then of course mark this also with the compasses and outside of the ventilator line.

Suppose you have the apron worked up and fixed, and you require the pipe or ventilator to stand *over* the turned-up edge, that is to say, to terminate on the roof for the ventilation of a granary or brewhouse, &c.; then you require to cut your lead to fit without guess work, and to stand perfectly upright with the roof. This is very easy to do with a piece of pipe, for then you may cut it to the mitre with a saw in a similar manner to that described in Mitre Block, Figs. 161, 162, &c. But, however, we do not want this kind of work. As the ventilator is 2ft. in diameter, or perhaps 4ft., we have to cut the lead exact, which may be done as follows:—

Let A, B, Y, Z be the size of the ventilator. Having marked this out on some lead or otherwise as before in Fig. 1,397, take the angle or pitch of the roof, called the "roof line" (see Fig. 1,398); next strike the plan of ventilator C, and be very particular about the points. Draw the line D, J, G, which may be, if you like, the height of your ventilator or otherwise. Next divide the plan as shown, from 1 to 15 into any number of equal parts; through these points draw the lines 11, 12, 13, 14, 15, &c., from the plan to the roof line and parallel to the sides of ventilator. Next mark off on the line D, G, the exact circumference of the ventilator, which may be done with the compasses by dividing the circle or plan into any number of equal parts, and again by setting same off on the line D, G, taking care to use K as a centre line or point. Now, you have on the line D, G, the exact same number of divisions on each side of K, as you have in the half plan. Number them as shown, and draw the lines K, L, 1, 1, 2, 2, &c., which must be parallel to the sides of the ventilator or square to the line D, G. Then make the line K, L, equal in length to J, Y and H, F, equal to D, Z, and also each of the upright lines on the line G, D, equal in length to the line drawn from plan to the roof line, as at 15 (roof line) and O, L, 14 (roof line), and 1 near L, &c. Then draw the curve line, L to M, and L to Z. This will be the true shape to cut the lead for the required ventilator. Remember, always get the bevel or pitch of the roof and upright of ventilator.

Covering Cones, Turrets, and other Spires. Also see Trumpet Wastes and Ventilators.

I have described the method of cutting out the lead for a round ventilator, and now let us see the method for cutting the envelope for a cone or spire. By the way, cones are often used for malt and other kilns, so that this must be part of our work on ventilators; and, further, it is not at all uncommon to cover small spires with lead; sometimes the base of same answers the purpose of finials.

Let us take the work most common to the trade. A trumpet-mouth waste is cut cone-shaped, but generally it is cut by rule of thumb—that is to say, the lead is cut large enough, the sides prepared and turned up on the mandrel, the ends trimmed off when soldered, and perhaps it is quite near enough for all ordinary purposes. But this is not near enough for the larger kind of work, such as spires or turrets, Fig. 1,399, and malt house kilns, &c. (Fig. 1,399 shows the turret spire finished and covered with lead.) Fig. 1,400 is the cone envelope or lead cut for a trumpet-mouth waste. I speak of this because it is the simplest to cut, and most known to the trade (see Fig. 57, Vol. I., and description). Another way, Fig. 1,400, shows the

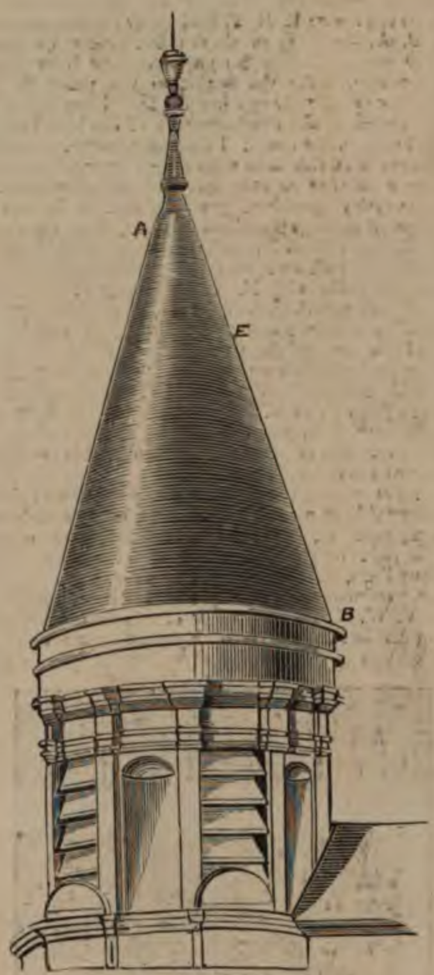


FIG. 1,399

FIG. 1,400.

geometrical method of striking out the cone envelope. Let A, be the apex; E, D, F, the base or half-diameter; and E, A, F, A, the sides or slant sides. Now we want the cover for same. Take the compasses, and from the apex A, as a centre, strike the arc from the point F, to H, carrying the arc far enough toward H. Then make F, H, equal in length to the circumference of the base line E, F, which, of course, is a circle. I find, in practice, it much best to measure round this base with a very narrow slip of lead, the same substance as that intended for the cover. Of course, properly speaking, you can find it in the same manner as obtaining the size for pipes, &c. Or this, the size of the base from F, to H, may be simply obtained approximately, and near enough for working lead, by first striking the half-circle, E, F, D, taking J, as a centre, which, of course, will be half the diameter of the base line; then dividing this into any number of parts, and as many parts as there are, set same off the arc, F, H. You must remember to double the number for the total circumference, as the half-circle E, D, F, is only half the plan, and would only reach from F, to K. By striking the arc C, G at any point you may wish, you can obtain the cloak or cover for any given frustum of a cone. Of course, this arc must be struck from the apex A, as a centre.

Fig. 1,401 shows the method of covering and fixing a cone up the side of a roof, which may be demonstrated as a conic section. A, B, is the true base line of the cone, and E, L, the plane or roof line which cuts the cone. Having there four lines, that is to say, the sides, base, A, B, and roof line, you will see the shape of the cone. Next make the arc, V, W, X, &c., from the centre of base line, as at Q; then divide this, say, into nine parts or more (the more

FIG. 1,401.

the better), and from these points in the arc, W, Y, X, &c., set up the lines V, to M, W, to N, &c., square to the base line, A, B. Next draw the slant lines from M, to D, N, to D, &c., and where these lines intersect the points of the roof line, L, E, &c., draw the lines, L, 11, K, 10, J, 9, &c., parallel to the base line. These points are very important, and must be carefully watched, otherwise the work is useless.

Next comes Fig. 1,402. First take the distance, from D, to B, Fig. 1,401, as a radius, and at D, Fig. 1,402, strike the arc, A, Q, B; next divide this arc from Q, to B, and Q, A, into just twice the number of parts to what you did in the arc, A, V, W, &c., Fig. 1,401. It is very important that they are of the same number and size. Next draw the lines, A, to D, B, to D, E, to D, &c. Next take the exact distance from (the shortest line, E, to 4) E. to D, Fig. 1,401, and with this length measure off from D, to E line, Fig. 1,402, and also from F, to D, Fig. 1,401, and mark off the distance on line F, D, Fig. 1,402, and so on until you get to L, and repeat this on the left-hand side of the figure, as shown—these distances give the curve line from A, to Q, and from Q, to B, V—when the thing will be ready for cutting out. Allow for a lap or welt. This cone is very handy for fixing up the side of a roof as a ventilator. The method of fixing is to first fix an apron with a stand-up, say, of 6in., all the way round, then this

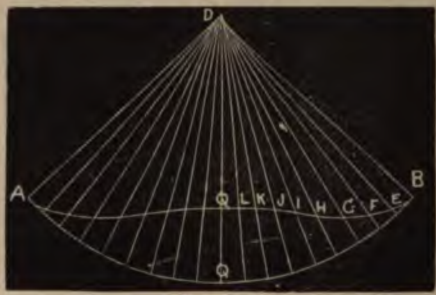


FIG. 1,402.

cone is made 6in. larger than the stand-up part of the apron, the cone fitting over same, leaving a clear space for air or ventilation. These cones look much better than cylindrical top ventilators. Of course you see the method of measuring for the lead is described in Fig. 1,402, and you can also see that the same method of striking out will answer for hop or malt kiln tops, those working on swivels, &c., always keeping their mouth, or properly speaking their outlets, away from the face of the wind.

Aprons for Cones going up and through Slanted Roofs.

If you examine the apron, Fig. 1,397, which is to work up and fit round a cylindrical object, you will at once see the method of cutting the same will not suit for a cone such as is shown and described at Fig. 1,401, for if the base of the cone is the same size as the cylinder, Z, Y, Fig. 1,397, the apron, as cut for the cylinder, would be too large for the cone. This can be at once seen by chalking out a cone and a cylinder side by side, and drawing the angle or pitch of roof thereon. You will also find them different in shape, but do not become disheartened at this formidable-looking lot of strokes and rings. The whole thing will soon be learnt by heart. Remember this, that quite as much brains are required in the head of a plumber (doing his work properly and in a systematic style) as in that of any other man, styling himself a professor, engineer, or architect. I have heard it said that if a lad has no "headpiece" he will do for the plumber's trade, and will do as he is wanted to. A truer word was never spoken, for he will not trouble which way the water runs, whether through pipes or air—often preferring the latter. As to the word "plumber," if you have taken notice of my first volume introduction, you will there see that a plumber knowing his trade is by no means an ordinary person, for he should be able to make calculations, drawings, understanding sufficient chemistry to protect himself against the different acids and other chemicals which have an important effect on lead and on other metals, and engineering as far as regards pumps, water-closets, baths, and a host of other sciences. Fancy! I was articled to a civil engineer, was engaged on the Hereford and Worcester Railway, taking levels during the greater part of that time

in the Malvern tunnel. Was also afterwards apprenticed to a plumber, and have my indentures, from Mr. Wm. Brock, late of Worcester (who is, I am pleased to say, now living the life of an independent good old English gentleman near me at Kensington). Was five years in the employ of Mr. John Jay, the eminent contractor, on railway work (the Seven Oaks tunnel), and also with him on the Metropolitan Railway (Euston, &c.). Have worked on board ship, in the docks and out. Was engaged on the plumber's work (general foreman for Messrs. Jackson & Shaw) at Burlington House (Royal Academy). And three years in the foundry and engineers' workshop, having the whole under my sole control. I then retired from the trade to complete my knowledge of Pitman's system of shorthand, for which I now hold a certificate for teaching and as a qualified member of the art. I am again still in the trade, and always will be, and this is my advice to apprentices:—Stand second to none. First learn to read and write, work figures perfectly, do drawings neatly, and, in your spare time, work the level, study metals, building constructions, engineering, chemistry; take notice that everything that you do is done scientifically and in reasonable time; if possible, learn Pitman's system of shorthand—it will save much valuable time.

Just another word, which may be interesting, which is relative to why I took up with the plumber's trade. It looked something to learn; it is a mechanical trade, and a trade required in all parts of the globe. If you choose you can learn to tell the weight of a piece of iron, &c., calculate speed or strains, judge distances, make drawings, and sum up, sound a brick, stone or piece of metal, pour out a pot of metal into a flask of greensand, or work a press, rolling mill, sulphate plant, cast all kinds of lead work, design moulds of the most complicated forms, in fact, become a most interesting member to mankind, and, at any rate, quite equal to those who are not plumbers. I want you to be thoroughly acquainted with your work, both theoretically and practically, and competent to undertake large or small constructions; but by all means become a good workman in that interesting metal, lead. A man should never consider himself a first-class plumber until he feels competent to work with any man. It is my one great object to raise my brother workman to the highest level of all mechanical trades, and I hope to do so.

Through these pages I will endeavour to show you everything which I have learned connected with this, our trade; but it will be impossible for you to become first-class if you cannot systematically mark and cut out your work. The illustration, Fig. 1,403, before you looks, as before said. formidable, but this is nothing. You should see some books on trades, such as Peter Nicholson on Handrailing; and, after all, his lines of handrailing are only the same thing as those used in some parts of our work.

I think I hear you say, "How shall I begin this cobweb?" Fig. 1,403. Well, proceed as follows:—First, look at Fig. 1,401, notice the roof line and take the bevel of roof and cone at its highest point up the roof; then set out your cone from A, to B, Fig. 1,403, and B, to C, always making the centre line, D, square to A, C, but carry D, well up above the apex. Next take your bevel and mark the pitch or roof line to the cone line, A, B. With equal distances on the roof line, draw the horizontal lines E, F, G, H, I, J, K, parallel to the base line, A, B. These lines, E, to K, must cut the one or both slant sides of the cone, as shown on the left.

From the outside points of the horizontal lines which cut the slant line, A, B, to the perpendicular line, D (that is to say from A, to T), with compasses measure this distance, which is half the diameter of the cone, and with this distance strike the circle, M, V, using the line, D, as a guide in order that it shall be central and dead true over the base of the cone. Then measure off the next horizontal line, L, to E; strike this size circle inside the last, and so on until you have measured and struck all the lines from T, to K, and the circles from M, to P. Draw the line, M, V, parallel to the base line, A, C. You may use as many horizontal lines in elevation as you like, but they should be of equal distance apart and true with the other. Having done this you will have the point on the roof line as at 1, 2, 3, 4, 5. Then draw the lines, 1, 1, to cut the point, 1, and the circles, 8; 2, 2; 3, 3; 4, 4; 5, 5; 6, P;

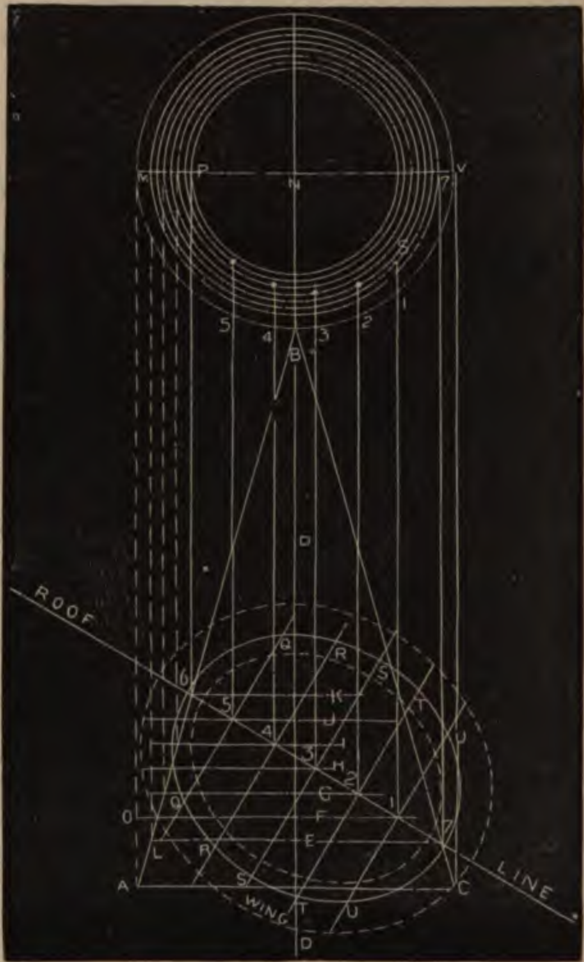


FIG. 1,403.

7, 7. You must be particular with these points and measurements. Notice that each perpendicular line starts from the roof line point of the horizontal line and goes to the same circle that was struck with this radii—it will be quite as well if you adopt this plan of putting dots on the circle so as to tell which is which. The next are your square lines, to the roof line: these are shown by Q, Q; R, R; S, S; T, T; U, U. They are drawn through the points of the horizontal line, and cutting the roof line square, as at 1, 2, 3, 4, 5. Next, with your compasses measure down from the point, N, on the line, M, V; to

the circle, 8, where the line, 1, 1, cuts it. You see that this is an important point. Take this length from the line, M, V, to the cutting of the second circle by the line, 1, and measure off on the square line, 1, to U, this distance. Next take the distance from the line, M, V, to that point of the third circle where the perpendicular line, 2, cuts the circle; in this case it is shown to be the fourth ring. With this distance measure off this distance on the square line, 2, T, T. Next measure the distance from M, V, to the circle where line 3, cuts, and with this distance set off the points, 3, S, S; next 4, R, and 5, Q, as before. Then you will have point on the square lines at Q, R, S, T, U. Draw the curved line, which will be the true line for you to cut, or turn up your lead to. The outside dotted lines are for cutting the outer edge of the wing or flashing, and the inside dotted lines are for the turn-up. These are scribed round with the compasses. Of course you must work the turn-up with a bevel as best you can.

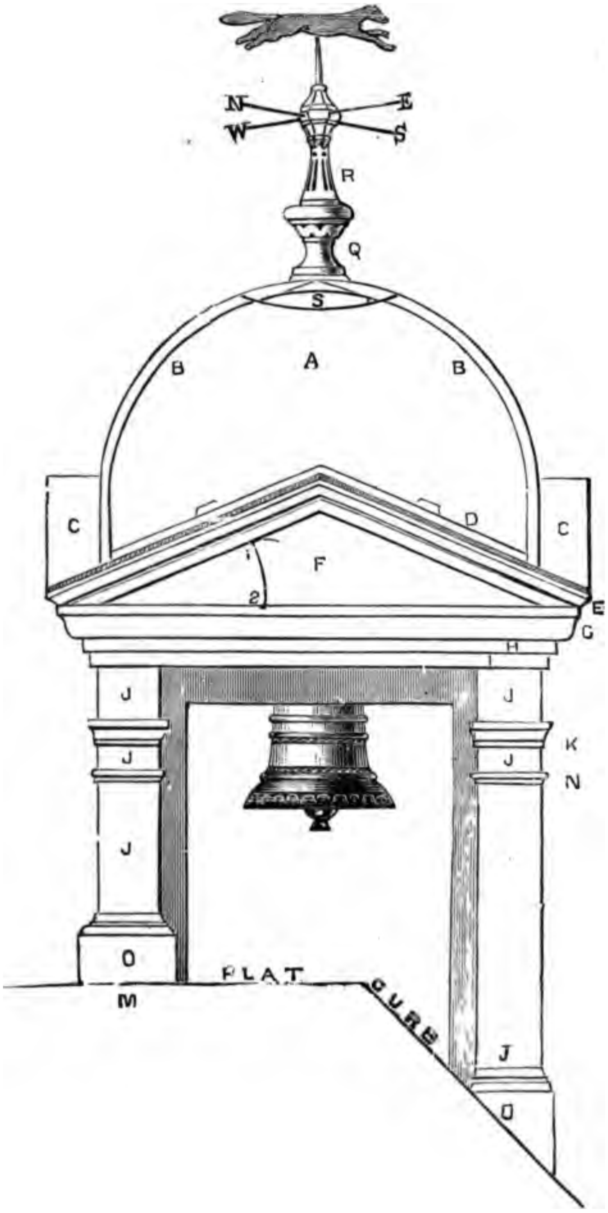


FIG. 1,404.

Turrets.

There are various kinds of turrets, but the kind we have to do with is that attached to a building as illustrated at Figs. 1,406 and 1,407. It can at once be seen that its situation generally extends above and beyond the highest point of a building, so that it at all times appears conspicuous, and by no means sheltered from storms. The uses of the turret are various, often used to point out the four quarters, E. W. N. S.; but it is, as a rule, occupied by a bell, as is shown at Fig. 1,404, and hence another reason why it should stand high, so that its occupant's tongue might be heard at noon.

> "Which makes the ploughman's heart rejoice;
> At twelve he hears its tuneful voice."

Fig. 1,404 is a turret which I lately covered. Its plan is a square, the top rounding off to a point. Its top has four bays, as at A, going to an angle, as at B, B. The under cloaks of these bays are nailed on up the four angles, and the over cloak turned over to form a welt. The lead on the flat part or gables, C, C, is put on by turning it up so that it goes 5in. up the top, A, and over the flat part, C, of gable. The lead, as shown by the sectional lines, overhangs the front moulding, as at E. E, is a moulding covered with lead and afterwards stuck on all round. F, is the fascia, which goes up and under the moulding, and the bottom part is worked over the moulding, G. This is struck geometrically (see 1, 2). G, is another ogee moulding covered with lead. This lead is worked round the front of the moulding and about 2in. up the back, where it is nailed, but covered with fascia lead. The lead on H, and I, is in one piece from corner to corner, where it laps to form a joint. The lead on J, J, J, is put on and goes up under

FIG. 1,405.

the lead at I, and down over the stand-up of lead on flat at M, and also over the turn-up of flashing at L, or O, the moulding, K, being covered, and afterwards wiped or soldered to J, all round top, also the bead, N. The plinths,

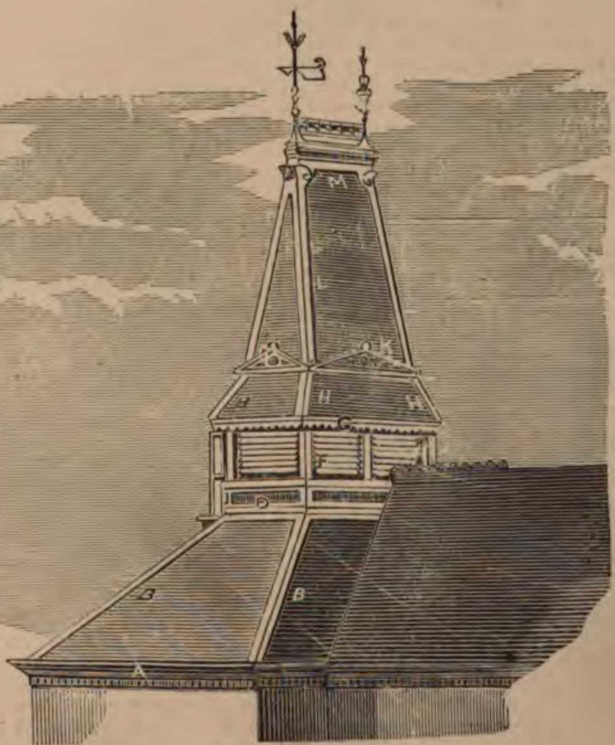


FIG. 1,406.

O, O, are covered and then put on, and the small moulding, P, is formed with solder and wiped true and square at corners; or it may be cast and soldered on. The woodwork of Q, is first turned true and then carved. The part Q, is in one piece and R, in another piece. Q, is covered by first working the lead up like a half ball, or like making the lead for a domicile strainer, then dropping it over Q, (the woodwork) and dressing it round the hollow, which, if struck forward, will cause the molecules of lead to flow forward to form the apron, S, which may be worked down nice and firm on the bays. Next, the cone part, R, is to be covered. This has a seam placed behind; it is worked so that the bottom part will come over the top member of Q. Then the weather-cock (or rather the fox) with the block and pointers E. W. N. S., which has a rod of iron made to pass through R, Q, and the lot is screwed down to the under side of the top of the turret.

The method of cutting the bays, A, was by first cutting one piece large enough, then with the bevel mark out the pattern for C, place the lead on top and scribe corners, B, B, on lead, cutting same, but allowing enough for lap and welt. For the different methods of cutting same see Domes, which will follow.

You have seen how to cover this turret, Fig. 1,404. You have also seen that it is used as a bell tower, weather-cock, and a pointer to the four quarters; it is also used for another purpose—it is used as a lightning conductor. You know that the block supporting the vanes is fixed with a rod; let this be of copper, the lower end of which attach to the ordinary lightning conducting wire or rod, and convey same to the ground into the damp soil, drain or well. But the form of rod for this purpose is made to the shape of a spike having points, as that shown on top of turret, Figs. 1,405 and 1,406, and also that at the finial, Fig. 1,483, &c.

Fig. 1,406 is an enclosed bell turret, and although it appears a simple piece of work, yet there is a lot of plumbers' work upon it. We will suppose that the bays, B, B, are laid, and the rolls covered; we begin by first fixing the lead work panels, D, and worked up to the louvre posts; then fix the scalloped work, G. Next, the short hips, H, H, H; then the gables, K. Next put on the hips (if they are not worked on with the gables), which are best in separate pieces, then the top with finials. The top flashings round M, are, in this job, scalloped work, to match that at G, and there is also a hanging flashing round the gables.

Fig. 1,408 is a shooting box turret, partly slated, the hips being worked with soakers. At the gable ventilator, or pigeon holes, A, our work commences. First, we put on the bays A, then the scalloped apron, which is well nailed and tacked down. The soffits and gables are the next to cover; these should be cut sufficiently wide to turn up against the spire roof for the slates, if used, to lay upon, and also to come over and turn down, and nailed over the front of the gables in such a manner that it will be impossible for the least wind to get under the lead.

This is most important, and one of the principal features to keep in view when covering any roof which is likely to be exposed to the wind, or strong rays of the sun. D, is the capping piece (see Finials), which should be cut to its right shape (here the rudiments of geometry will be handy) when put on in one piece, which is generally the case, and the joint welted on the side least exposed to view. Fig. 1,407 is a turret having a kind of ogee top, the sides of which are worked with five bays on a side, all the lower part is covered with lead, the bottom corners are worked first, and the angles welted together with flat welts, which keep the work snugly together. There is one thing which will require your particular attention, that being the nailing part, for when nails are used in juxtaposition with welts, they should be placed in such a manner that they will be covered with at least 2in. of lead, and put in such a manner that the welts will hold the lead in its position as though the nails were not there;

FIG. 1,407.

FIG. 1,408.

or, in other words, this turret, which has five 2ft. wide bays, is with welts worked in such a manner that it will stand well together, irrespective of the nailing.

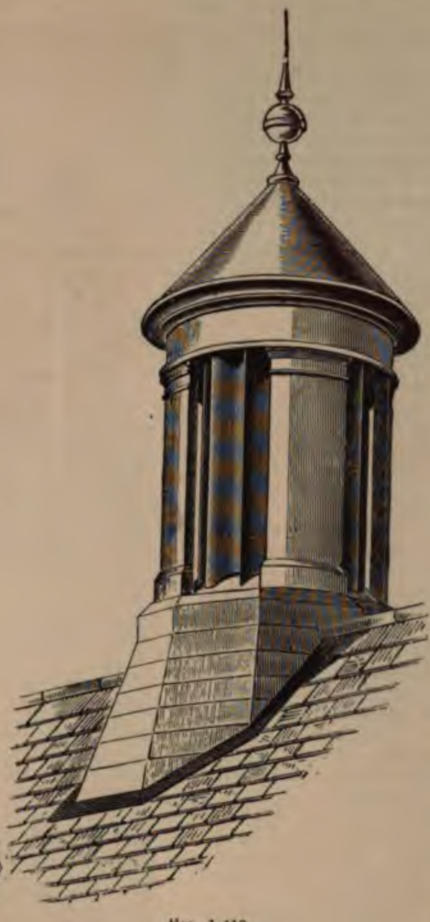


FIG. 1,410.

FIG. 1,409.

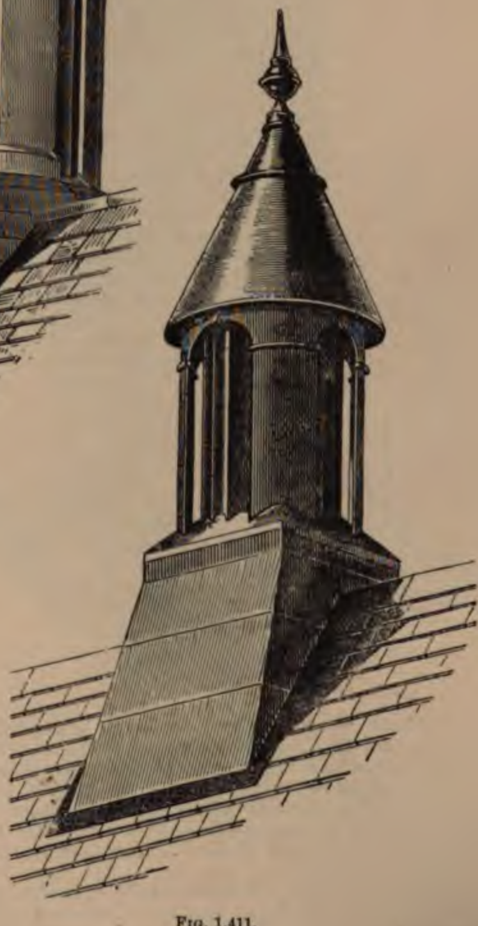


FIG. 1,411.

Ventilator Turrets.

Sometimes the turret is made to answer the purpose of a ventilator, as illustrated at Fig. 1,409, which is a first-class piece of work. This diagram shows the flashings, the mode of slating, also the hips worked with soakers, and the curb covered to receive the pillars. It also shows the guttering made to act as a finish to the bottom of the spire part, also the bays and finial, and altogether is a very good piece of workmanship. The above is extensively made by Messrs. R. Boyle & Son, as are also Figs. 1,410 and 1,411, which are excellent pieces of lead work.

Turrets and Spires (Fig. 1,412).

This is an ornamental turret with spire top. A, is the part where the wet generally gets in. The best method is to line the base part, B, with a separate piece of lead to that going or laying on roof, and work it in as small pieces as you possibly can, taking care to have sufficient welted laps. The latter is very important. In this niggling work plumbers are apt to think that a smaller lap will do here,

FIG. 1,412.

and this is one reason why you require to be so particular round A, and B. Use soakers up the roof at A. Never trust to close nailing at this point, as close nailing is only suitable in places that are often painted, which, of course, such a piece of work as that here shown never is. This is all covered in the same method as the turret, Fig. 1,404, including the openings at E, D. The drawing is too small for general detail.

Fig. 1,413.—This is a bell and ventilator turret having its upper parts raised, as spoken of when describing Fig. 1,412, which see. You will at once see that soakers are used up the hips of the roof, that finials are fixed as a finish at A, the top, that the whole is resting upon brickwork, and that there is but little plumbers' work to be seen, excepting the unsightly pipes, P, P. You see that it stands on ten posts, which are let into a frame inside the brickwork. These posts, D, and frame are covered with lead in such a manner that the water is brought with pipes, P, P (drawn too large), from the inside to the exterior; if it were not so, of course the water dropping

FIG. 1,413.

off B, on to the frame would soon rot the latter. This is a job I have done, having a large water tank on the top.

Dome or Spherical-shaped Turret Tops.

(Fig. 1,414.)

FIG. 1,414.

This is a bell and ventilating turret, having a duodecagon, or a twelve-si[illegible] for its cover, which will require

your particular attention in cutting it out, which is done as follows—a good rule of thumb:—First, with a tape take the length from top to bottom of the front bay, and the width across the centre at A; allow a little wider than wanted, then divide the top part into two or three more parts, as across at the line, B. This divides the bay into four parts. Take these measurements and mark them on your lead and you will be very near to the shape. Notice the more parts you divide the bay, A, into, the nearer will be your shape. After the lead is cut put it in its place and scribe to the angles. This is called rule of thumb work, but in practice it is for certain reasons quite as good as the geometrical method, but when you have to make small ornamental globes in pieces, without a frame or wood work, then it is a very different matter. Here geometry is handy, and the work cannot very well be done without it. Well, then, let us see how to work this, Fig. 1,415, by geometry. First strike the size of circle

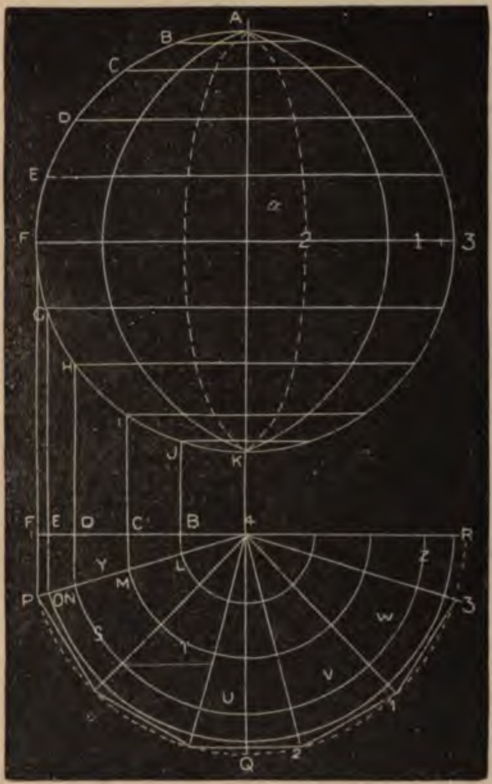


FIG. 1,415.

required for the globe, as at A, F, K, and 3, and draw the horizontal line, F, 3, through the centre. Next erect a perpendicular line, A, K, extending K, some distance below, as at Q; now divide the circumference of this circle, A, F, K, 3, into any number of equal parts, as at A, B, C, D, E, F, G, H, I, J, K, and draw lines across the circle as shown, the lines to be horizontal and parallel to the line F, 3. This is the circumference of the circle divided equally. Next draw the half circle, which is to make a half-plan, so that this must be of the same size as half the globe. Having the half-circle for the half-plan, draw the horizontal line, F, R. The circumference of this half-plan is next divided into just half the number of parts as there are flat or face sides to your globe—the globe has twelve, then the plan must have six equal parts, that is to say, five whole parts, as at S, T, U, V, W, and the two halves, Y, Z (these halves are the principal, as you will see). Next draw the half-circles L, M, N, O, and from the ends on the horizontal line which cuts the circle at F, G, H, I, J, draw parallel lines to the centre line, A, Q. These lines are to cut the line P, 4, as at P F, O G, N H, M I, L J. Then where you have cut the lines, F, R, and P, 4 are the distances to be set off on the line A, K, Fig. 1,416. First, with the compasses measure

FIG. 1,416.

the distance between plan L, B, Fig. 1,415, and transfer this to the line, B 5, Fig. 1,416, which is one point right. Next measure M, C, conveying this measurement also to Fig. 1,416, at C, 6, then go to plan and measure D, N. Put that to D, 7, then O, E, place this to E, 8, then F, P to F, 9 with the same gauge. You should have come up from J to F, Fig. 1,416. Do it, and where the points are marked draw a curved line as at A, 5, 6, 7, 8, 9, K. This will be true to the line and will make the shape required. To find the curved line, A, 2, K, measure these points, B, 5, 5, C, 6, 6, &c., and transfer the measurements to the centre line, A, K, as shown by the dotted lines; but for the second curve, A, 1, K, set a perpendicular line from the point at 1 in plan, to the centre line in the circle, as at 1. If this line is upright or parallel to A, Q on line F, 3, then 1 will be the point. Then draw a curve (part of a circle will do) from A, to 1, and from 1, to K; the same

on the other side. The curve, A, I, K, is easily formed by the geometrical rule known as drawing a circle through any three given points.

You have seen the method of cutting out a twelve-sided circular dome. It is obvious that the same rule can be applied to any other figure having a number of sides. A true dome is half a sphere, the curved surface of which is at all points equally distant from the centre. Most domes are not true in shape: they are more of a half spheroid, or the shape of half an elongated sphere, something like an ellipse in its side elevation. Let us now see the simplest method to cover a dome of this true shape. I have said the simplest way; I also go further and say that it is also much the best, and a method, if properly done and small pieces used, which will last, in a comparative way of speaking, till Doomsday. Besides, it is so simple, and next to no labour in the work. Just compare this to Fig. 1,417 and Fig. 1,418. But, say you, the one is ugly, plain, and the others light and pleasing to the eye. And here it is where the workman is required. Some domes are covered by piece after piece until you come to the top, when a good crowning or capping piece is used for the finish, and the ball and cone with copper or brass spike on top. Of course, when the bottom edge of the lead is not welted, then tacks are used.

FIG 1,417.

Fig. 1,417 is a panelled dome, like the dome of St. Paul's Cathedral, London. It is rather too elongated, and requires a cross, as shown in Fig. 1,419. Let us see how this Fig. 1,417 dome is covered. First there are gutters all round inside the ornamental railings at A. These gutters are cut and worked circular, having drips as other gutters. The method of pulling or turning them up is to a template, one for the inside and another for the outside. The stand-up against dome is, or should be, at least 6in. to 18in. high. Next comes the panels. They are made like the safe of a w.c., bossed up at the four corners to suit the mouldings. The top and sides are let down into a rebate flush with the rails and mullion, and well nailed there. But the bottom of panel lead, of course, has no nails, but discharges itself over and on top of the mullion lead below. This mullion lead is only a short piece extending from roll to roll. The rolls are put on last, but in some cases the rails between panel and roll are from 9in. to 12in. Then the rail is covered with a separate piece of lead and worked into the panel. The roll lead then comes over the rail lead sufficient for laps about 4in. or 5in., having strong tacks every 12in. or 15in. fixed in a slanting direction towards the gutters, so that the water cannot run back to the tack. You now see how the gutters, panels, stiles, mullions and rolls are put on. You see there is not much in this after all. Begin at the bottom, and find your way to the top. Be sure and turn every tack tight, and don't be afraid of driving a few nails—copper, of course. The capping piece is finished as in the bell turret. The reason why small pieces are used upon this work is to guard against the expansion and contraction. It is not at all uncommon to see copper on the south side and lead on the north side of domes and spires, but if you work your lead as directed in Fig. 1,417 it should, if cast lead, last at least 300 years, of course providing you have quality and stout, say, 10lb. or 14lb. lead. N.B.—The longest length used on such work should never exceed 8ft. in length and 2ft. wide, except the panels, which may be wider because they are shorter.

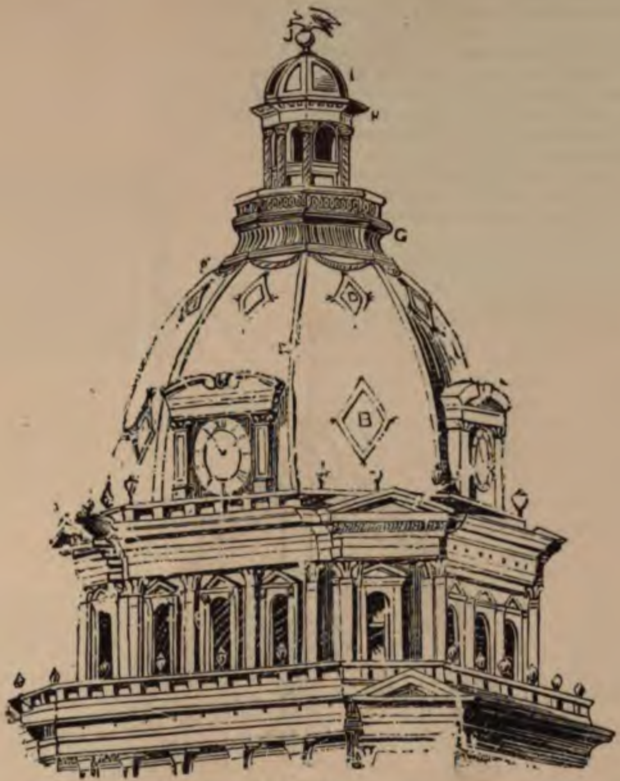


FIG. 1,418.

Fig. 1,418 is a splendid looking piece of lead work. The bottom part has gutters, as in Fig. 1,417. Next are the backs of the clock dormers. This has a cheek on each side turned up against roof or dome, the other side works in a chase sometimes flashed over with hanging flashings, then the hips are covered (the details of which were given in Hips and Ridges), but the wings are either welted or, better, turned into a secret gutter, formed all down within 2½in. to 3in. of roll. The panels are sunk with mouldings, and the bays are in small pieces and worked with flat welts. Next is covering the frames, and by this time I should certainly be inclined to trust you to do such a job. You are now at the top. Here is a torus for the bays to butt up against. This torus is covered with lead. This lead should form a flashing to go over the coves. On looking carefully at this point, you will see some scroll or drapery work to cover the tops of the bays. Sometimes this is worked up on blocks in the shop and other times cast to a pattern. The latter is the best, as it is required to be heavy and rigid. This curved work is too simple to need any description, except at the curved angles. As regards the straight part, it is cut out of a straight length of lead hollowed and flapped home with a flapper (see Fig. 43), the corners being worked round the top, inside and outside of railings are covered with lead, and also the turret, in a similar manner to that before described in Fig. 1,404. There is on this dome 159 tons of lead, without one atom of solder, it being the best piece of lead work I have seen; in fact, up to 1896, there is nothing to equal it, but it remains to be seen how it will last against such pieces of plain work as the dome of St. Paul's, London, which has proved itself to be the best piece of work in this country, if workmanship and material has anything to do with good work.

Fig. 1,419 is a very nice looking dome with good finish, but not so easily done as some of those described; in fact, it is about as hard to do as any I have seen. This is covered as follows:—First cover the cove or hollows 1, 2, 3, 4. If you look at the dotted lines at 1, 2, 3, 4, you can see what lap is given, the mitres at 5, 6, 7, 8, 9 are generally soldered, but if not, use water groves. You see that the lead for the hollow comes up and well under the nosing lead I, I, or sometimes under the bay lead, and is nailed with good stout nails to the round part of the nosing above K, M. For large work it should be put on separately and well nailed, and the corners soldered up. Next is the bays. Shall we cut them by making a template with strips of lead bent from top to bottom, having cross pieces tacked on to keep them apart? or shall we divide the bays into a number of parts, as that shown on J,N,C,E, &c., Fig. 1,420, by drawing horizontal and parallel lines and taking th[illegible] measurements? I think this is the simplest method kn[illegible] and quite as correct as any. Suppose you take th[illegible] and measure down the centre of bay from apex to Fig. 1,419, which would be J, M, P, the real vi[illegible] Fig. 1,420. Next divide the bay B, Fig. 1,419, in[illegible] equal parts, as shown by the dotted line between G, a[illegible] Now take the exact distances between the rolls at F[illegible]

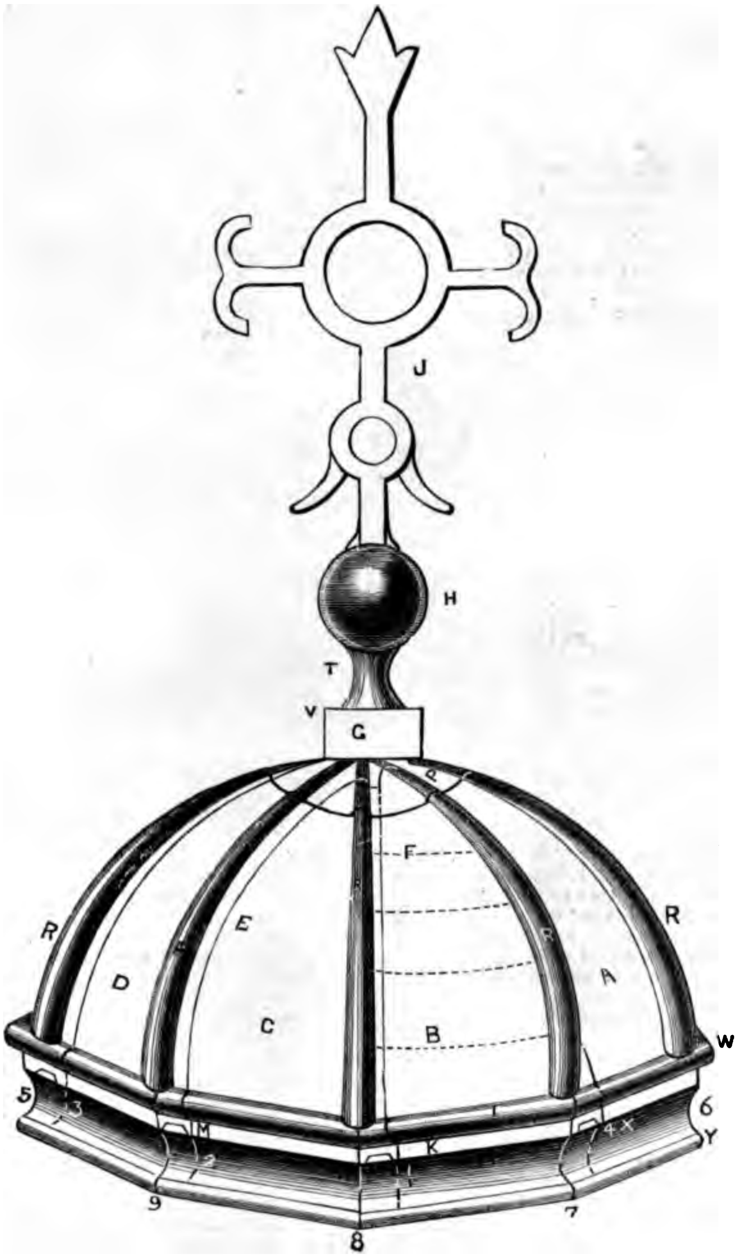


FIG 1,419

other lines down to B, and transfer these distances to the upright line in Fig. 1,421, as shown at 13, 14, 15, 16, and also at 12, 11, 10, &c., and M, H. This will be the true gauge for the bay; but remember to allow for the under cloak and over cloak. The proper way to cut this out geometrically is as follows:—Take Fig. 1,420. This is the size of the dome required. J, K is the base and P, the apex. C, E, H, P, the bay, also L, N. Draw the quarter circle G, D, E, Fig. 1,421, and to this the horizontal line G, A. Next erect a perpendicular line P, A to G, A from the top of th- -ircle at E, and up the perpendicular line. Set · point at P, which is the length

from apex to base of dome, as at P, M, J, Fig. 1,420, and also at G, D, E, Fig. 1,421. Next let this arc, G, D, E, Fig. 1,421, be equally divided, as at 1, 2, 3, 4, and draw through these points the dotted lines 1, 5, 2, 6, 3, 7, 8, 4, 8 parallel to the base G, A. Next divide the line E, P into the same number of equal parts as those in the circumference of quarter circle as from G, I. Place the line F, this distance from the point P, then measure from 1, to 2 on the circumference of the dome, and place this distance on the upright line as from F, to C. Then measure from 2, to 3, and place this on the upright line from C to N. 3, 4 is equal to N, B and B, E equal to 4, E. Draw the parallel lines, 13, 12, 14, 11, 15, 10, 16, B, M, H on the perpendicular line P, E. Next set off the distance or bottom width of bay, C, H, Fig. 1,420, on the horizontal line, M, H, Fig, 1,421, and draw the line A, M, A, H, cutting the horizontal lines 1,2, 3, 4 at 5, 6, 7, 8. Next draw line parallel to the line A, P, cutting the points of horizontal line, as at 5, 6, 7, 8, 9, 10, 11, 12. 5, 6, 7, 8 are the points which give the width or distance for side lines from the line A, P. A curved line drawn through the points, 9, 10, 11, 12, will give the shape and half-size for the bay. With the compasses mark off the opposite side and strike that curve also. This completes the bay, but allow stuff enough for laps and rolls. In this dome the bays are drawn too wide; they are 2ft. wide by 9ft. long, with 6in. rolls.

FIG. 1,420.

FIG. 1,421.

Working-up.

Having the right size and shape, set up the under and over cloak, and bend them right back; then put the bays into their place, and hold it well up whilst you work back the under cloak side; then well nail it to the roll. Next work up the over cloak from top to bottom until it stands up square all the way down, then by degrees work the same about half over all the way down; then go back, and with the hammer and a short piece of roll (as in lead flat laying), the roll being held firmly upon the lead, strike the roll with the hammer towards the angle, and thus work it down without straining the lead. After this, with the hornbeam dresser and hammer, work it down middling close, and finish with a box dresser or long edge chase wedge. There should be tacks fixed on the roll to hold down the over cloak; but before you even attempt the rolls on a dome, you must do some on the lead flats, which has been explained.

To measure the superficial contents of a dome, the height and dimensions of its base being given, multiply the square of the diameter of the base by 1·5708, and the product will be the superficial contents. But for elliptical domes, multiply the two diameters of the base together, and the product resulting by 1·5708 for the superficial contents, which will be quite near enough for general purposes. But, of course, you must allow for overlaps, tacks, &c., and at times this will run to as much as 25 per cent., never less than 12½ per cent.

For the solid contents of domes or half spheres, having the height and dimensions of its base given, multiply the area of the base by the height, and two-thirds of the product will be the solid contents.

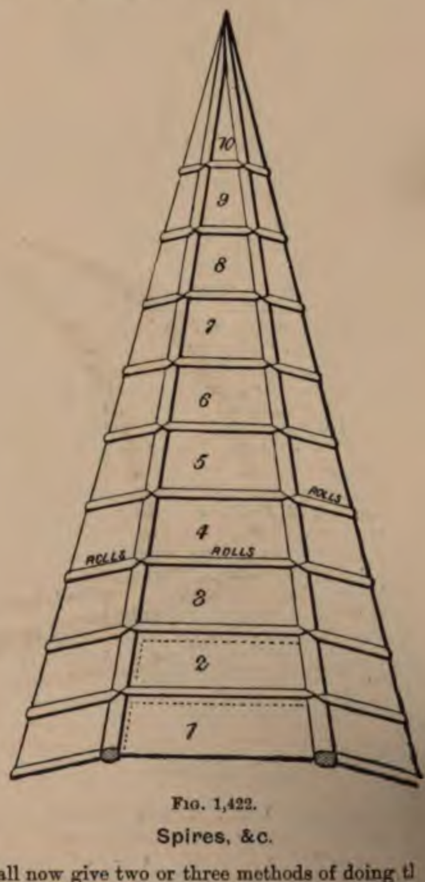


FIG. 1,422.

Spires, &c.

I shall now give two or three methods of doing th of work, although it is not one plumber out of twe

will ever be called upon to cover one. Hence the reason why I should go a little more minutely into the work. I will begin at Fig. 1,422. This is composed simply of straight pieces of lead nailed on to the boarding, as at 1, then the roll nailed on over the nailing of the first bay. Having the first bay properly nailed on, and the ends of the bays to the side rolls, next proceed to work the bay No. 2, which should be worked to form an over cloak to the first roll, and in such a manner that you can work the over cloak down round the roll, and leave a good splash lap properly tacked to prevent it moving. The rolls should be nearly round, so that the lead may rest well in the angle of the roll and boarding, which will prevent the lead from getting away. Having the bay No. 2 ready, put it in its place and *well* nail it along the top and down the side rolls. After this fix roll No. 2 over the bay No. 2, and so on, all up each side. In this method the ends of the bays are worked over the side rolls, or hips. Some plumbers lay the bays, and afterwards cover the hips with separate pieces of lead; but when this is done it is more work without getting any advantage.

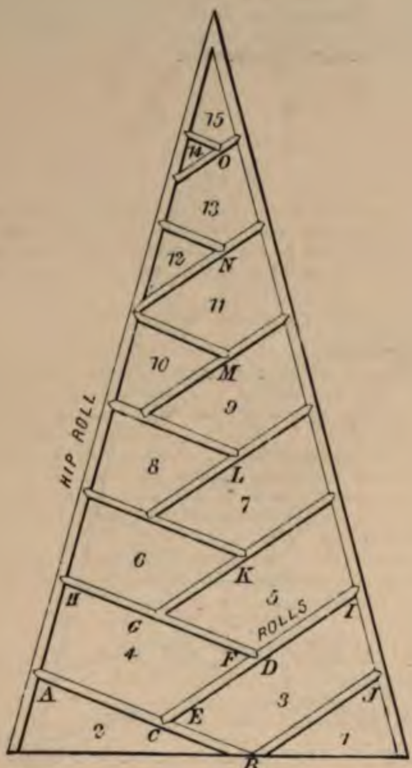


FIG. 1,423.

Zig-Zag Work.

This is shown at Fig. 1,423. It is very useful in places where long lengths of lead cannot be used, and where the bays are more than 9ft. long (see 1, 2, 3, 4, 5, 6, 7, 8). First fix the bays, either 1 or 2, with the under cloaks, as you did in Fig. 1,422, or as you would do in a common flat.

For my part, I prefer to nail the under cloaks under the roll, as from what I have lately seen this stands much the best, to say nothing about the work. Having got bays 1, 2, and 3 into their places with good rounded rolls and plenty of tacks, proceed to work down the over cloak over the first roll from B, to C, and from B, to J, and so on all up the spire. You may work the side rolls with the ends of your bays, or by separate pieces of lead, or preferably with the soakers, as before-mentioned. When executing this class of work there are several objects to keep in view. The first is perfect soundness of work. Second, that the pieces of lead put on are not too large, as they will be affected by the temperature of the atmosphere. Third, that the point of the rolls are in a line as at B, D, K, L, M, N, O, and their intersections perfectly worked; also that the other line of roll ends are running straight. These two lines of roll ends cannot be maintained unless every bay is set to a different width, which makes a great

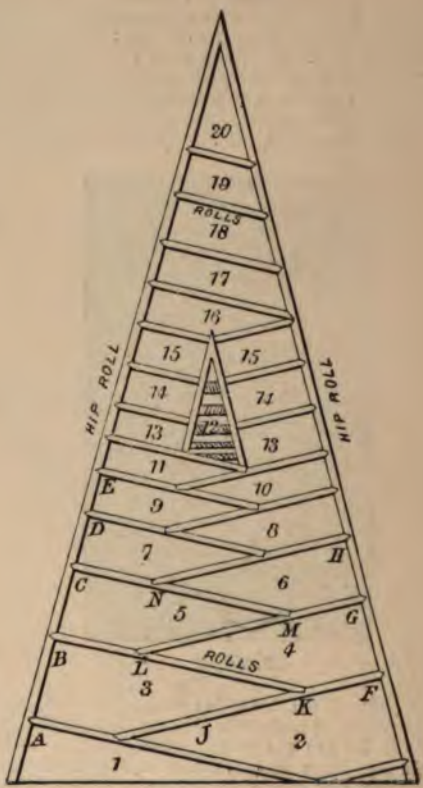


FIG 1,424.

difference in the cost of the work. Such work is shown at Fig. 1,424, and notice that it is impossible to work the ends of the bays at Fig. 1,423 on the square as in Fig. 1,424, namely, up against the side rolls. In Fig. 1,424, the ends of the bays may be cut square, A, B, C, D, E, F, G, H, &c., and if so, the bays will become smaller from the bottom upwards—that is, if the intersecting line is maintained. The top part may be varied, as shown at 16, 17, 18, 19, and 20.

Fig. 1,425 illustrates the lead as nailed under the roll, as at B, and the over cloak Q, K, A, covering the roll.

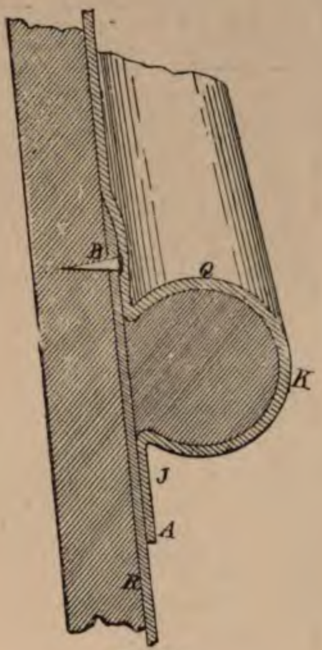


FIG 1,425.

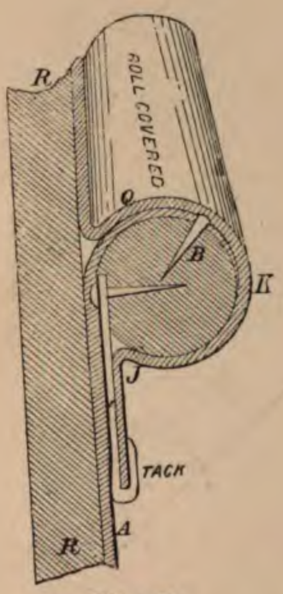


FIG. 1,426.

Fig. 1,426 illustrates the under cloak lead brought round the roll, as at B, and nailed on the roll, as at B, and the over cloak Q, K, A, brought over and tucked under, as shown at J with a burnt on, or otherwise fixed tack at A.

Fig. 1,427 illustrates the method of fixing the lead (as laid on flats) to the roll as in the ordinary manner, excepting the tack at A, which is here burnt on, or otherwise fixed for holding the return lead down. This fixing of the lead on the roll like the ordinary lead flat work should not be

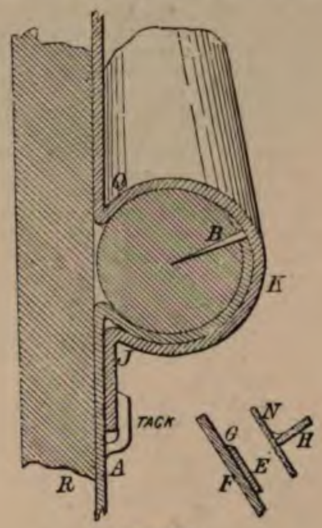


FIG. 1,427.

done on this class of work, for if the spire be very steep, and the sun anyway powerful, the lead will bulge out, shift downwards, and bag in the middle; but if the lead is well supported, as at Figs. 1,425 and 1,426, this cannot happen.

Diamond Bays.

This is illustrated at Fig. 1,428, and is the best class of work for all spire work, inasmuch as here the bays are not too large; and the fact of its shape renders it so that it causes each bay to wedge itself firmly into the mitres of the rolls, as at B″, C″, D″, E″, &c. Of course, the under cloak of the lead, as before spoken of, should be fixed under the rolls, which will also make the work more secure.

Before you attempt to begin such a job as that shown at Fig. 1,428, you should thoroughly understand the whole routine of plumbers' work.

Here is a job 240ft., or perhaps 300ft. high, and exposed to all winds and weathers. To fix up a scaffold, and put your work right after a few years would be a serious consequence; and, therefore, I warn you to do the work in as strong a way that you possibly can.

We will now reckon that you can carry out such a job, and prepare ourselves for a start. This is a job executed by myself; it is 140ft. from the ground, and 70ft. by 23ft. spire, which I began by covering the plinths, as at L; then put on the zig-zag casting L. Next I covered the fluted columns and caps, excepting the ornaments and leaves (which should be the last thing to do). Then the zig-zag panelling K, N, P, R, M, O, Q, S; then the curb flashing and curb roll as I have shown in the former part of our roof work. Work the bays in such a way that the rolls will hold the lead well down at every part, and where you can use ⅛in. thick copper tacks from 1in. to 2in. wide according to what the tack will have to hold, viz., put a 2in. tack in the centre of all lengths more than 2ft. long or wide, say, at such places as J, K, L, M, Fig. 1,428. The hip rolls up to 3in. will be covered by over cloaks from the bays. Should the hip rolls be from 3in. to 9in. diameter,

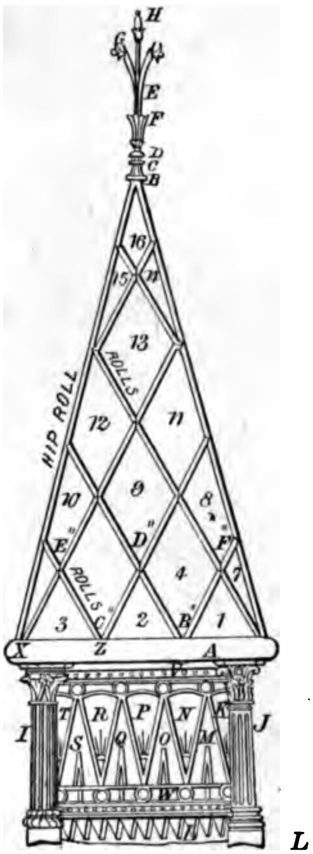


FIG. 1,428.

then put the rolls on after the panels are covered, and cover the hips, which makes a first-class job.

The finial capping is to be covered with lead, and the lightning conductors fixed last.

N.B.—No solder should be used on such a job, and I prefer not to have any lead burning. On this job there is not a speck of either.

Snow Boards.

Snow boards are used to allow the water to run off the gutters when the thaw takes place; they are also very good for protection of the lead whilst walking over the same. They are made as shown at Fig. 1,429. Fig. 1,429, A, A, are the blocks, about 2in. high, to support the crosspiece, D, D, upon which are nailed the fillets, B, B, B, about ¾in. to 1in. apart. These fillets hold up the snow off the gutter, but allows the water to run away as it passes from the solid into the fluid state.

Sometimes snow boards are fixed in a vertical position on the top of the slates in order to catch or prevent large lumps of snow falling off the roof on to glass verandahs, conservatories, greenhouses, and the like; and gutters, as shown at Fig. 1,316, will answer every purpose. But if the greenhouse is an afterthought, and built after the main roof is finished, or if you cannot have the latter kind of guttering, then the difficulty with the snow dropping is

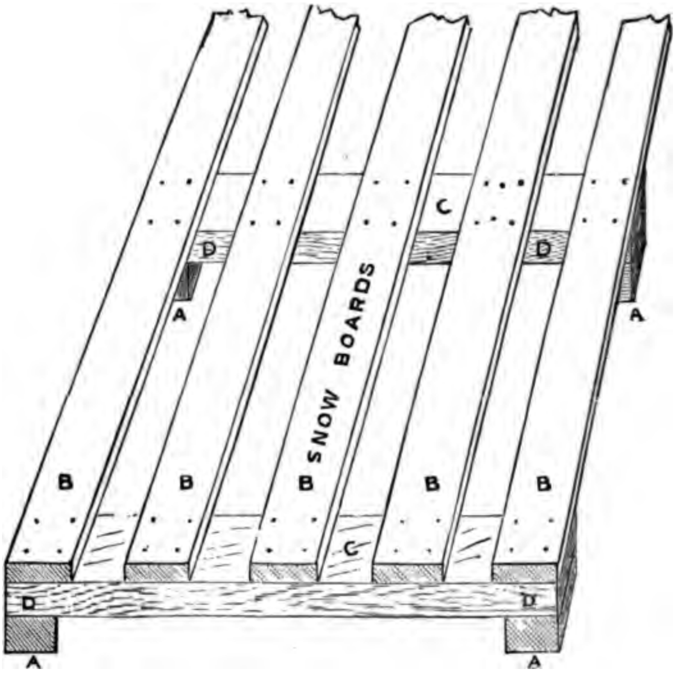


FIG. 1,429.

got over by fixing a vertical snow board, which is nothing more than a stout board, say, 1½in. by 9in., along the

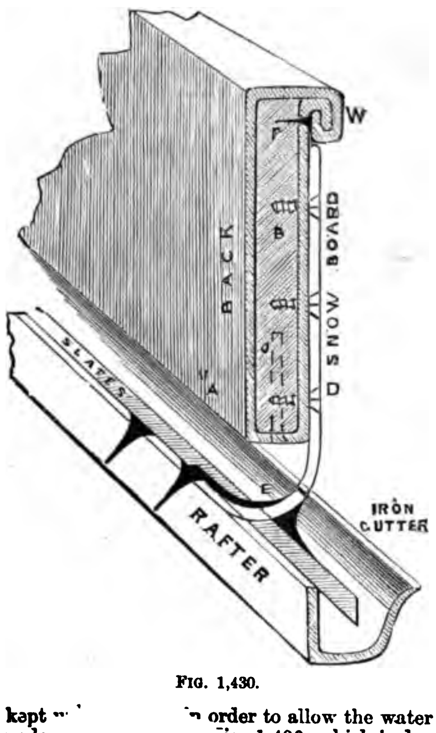


FIG. 1,430.

slates, kapt ... order to allow the water to get freely unde... ig. 1,430, which is drawn too

large. Care should be taken to have proper fastenings, which for a good job should be cast in gun-metal or brass. Of course this snow board should be covered with lead, and care should be taken to cover it in such a manner that when the snow is lying against it no wet can get to the board. Fig. 1,430 shows by an enlarged view the method of covering this kind of snow board, also the method of fixing it. B, the board covered with lead, and finished with a welt at W; D, the brass or gun-metal brackets, made good to the rafter, and at the point, E, made good with lead and solder. See that the brackets are screwed on, and properly covered with lead, or with white lead to keep the wet out of the screw holes; but a much better plan is to let the ends of the brackets be spike-shaped, and holes bored into the bottom of the board, as shown by the dotted lines nearer J; then drop the board on to the spikes, E. It will be much the safest plan to fix an apron of lead, say, 18in. wide and 12in. longer than the snow board, to prevent the wet getting in through the layer or course of slates just where the snow board is erected.

Roof Strainers (Cast).

These strainers may be cast to any shape or pattern. For cesspool work I prefer the diamond pattern, Fig. 1,431.

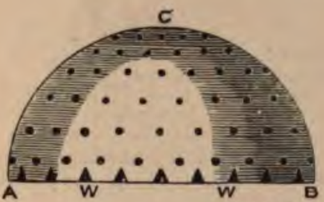


FIG. 1,431.

This is cast in the flask, the thickness of the bars vary according to the size of the strainer. Sometimes you will require them dome-shaped for fixing over the outlet pipes, &c. These may be cast in the same flask, but be careful to form the inside or core part to leave the pattern freely, otherwise you will not get on very well at this job. You may strengthen your strainer by mixing with the lead a small portion of zinc. Melt the zinc first.

Dome Bossed-up Strainers.

Suppose you wish to make a round or dome-shaped strainer. Let Fig. 1,431 be the required strainer, say 6in. across the line. Now take your compasses and divide the arc, A, C, B, into as many parts as you choose, say, 52; this is the distance round. Then take your compasses and set on a right or straight line 26 of these parts. This will give twice the distance for you to set your compasses, so that you may strike out a piece of lead to cover a ball this size with this radius. Strike a circular piece of lead, and work it to the required shape by first placing the outside edge of your lead to an angle upon the bench; then by beginning with the mallet, hammering away from the inside edge in order to make it hollow; then work it with the smaller dresser from round the outside, holding the large mallet inside; keep at it until you get it the required shape and size. Remember this, you must not knock it to make it thin round the top, but thicken it for strength. Having the size, strike a few rings round the outside at equal distances apart, and bore some ¼in. holes equally all round, or you may strike these rings before you begin to work up the strainer. If the strainer is bossed up, by the rule which I have here laid down, you will have it as it should be, thick round the bottom and top, which will be all the better when you put in the notches, W, W, and the holes.

Dome and other shaped Wire Strainers.

These are best made of copper wire for rain-water pipes, &c. They will last, but sometimes they are made of iron galvanised, which is poor stuff to stand for 20, let alone 100 to 300 years; therefore don't use them.

ORNAMENTAL RAIN-WATER HEADS.

Lead Rain-Water Heads.

Nearly every plumber has noticed the wonderful different designs we have in rain-water heads; and many, who have not had the work to do, are at a great loss to understand how some of these are made. I now speak from experience; for when I first joined the trade, and long after this, I was continually on the pry to find out the best shaped heads, and have made a collection of drawings of the old heads to be found about London, the different parts of England and abroad, many of which I intend placing before you. I have also designed a great number of rain-water heads, to suit the different jobs I have carried out, which I shall also place before you, and beg to state that the copyright of the same exclusively belong to myself. First of all, we will examine those easiest to shape. Before I proceed, allow me to state that if you can do lead burning you will find it a great advantage to you in this class of work, for solder should be avoided wherever you can. A square box—10in. by 5in. and 8in. deep, with an outlet pipe, having a simple bead or welt turned over the top to stiffen it—is one which is of the simplest known, called a square or cistern head. It can be cut out of one piece of lead, like the making up of a square service box or cesspool. This is, of course, soldered up, and a stump or socket pipe soldered in the bottom, which may stand up inside 2in. or 3in. in order to collect all dirt, or to form a ventilating-trap by putting a cap (like a bell-trap) over same; or if you wish to make this a call-head—that is to say, a head in the middle part of a pipe to receive another branch or a waste wipe, then in order to prevent gases escaping, bring the next pipe over the stump and give it what dip you can. Ears are soldered on, but if you cut the bottom, front, and two ends in one piece, and solder on the back, then cut the back to form the ears also, the ears should be large enough to hold up the head, and at least 6in. wide to turn back to cover the wall-hooks, and by so doing you prevent the wall-hooks from coming out, getting rusty, or staining your wings or ears with rust.

Figs. B, D, 1,432, is a head made in the year 1678, and has been in its present position ever since it was fixed in

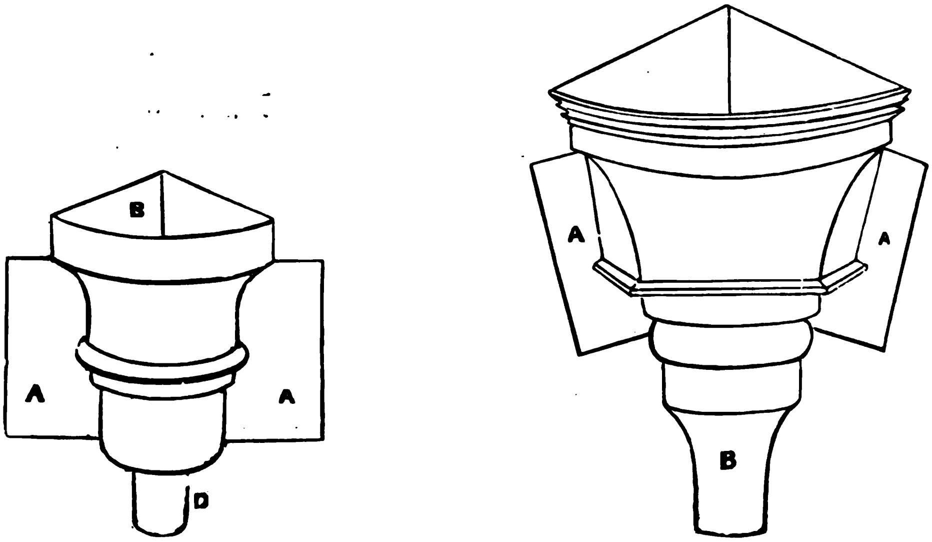


FIG. 1,432.

the Temple, London, and looks as good as the day it was fixed. It has a round front, with a kind of flat sides going to an angle, so as to form an angle head. Of course this is made on a block the shape of the front, and then the sides soldered on, also the ears, A, A. The method of working these fillets, abacuses, ovolos, annulets, colorinos, astragals, nosings, mouldings, &c. (architectural terms) in these heads are as follows:—First, have a block turned and carved the required shape, but notice one thing—see that it is made in such a manner that the lead may easily be taken off after it is worked. Then take a good piece of soft lead, cut as near as possible to the required shape, bend it round the block, and with a nail or two nail the ends of the lead round at the back. This fixes the lead on the block. Next, take a lead flapper, and flap the lead all round the different members so that you can see them quite plain. After this take some soft wood tools, made to the shape that will suit your work, and work all the members home, taking care not to work on the edges or arrises of the block or lead, or you will soon find bird's-eyes (holes) in the lead. It does not matter what the shape may be, you must remember this—the lead has to be worked home gently and evenly, and without the sign of a hole or the lead being strained. It sometimes happens that you can make the front in two or three pieces, or work in an astragal head-hollow or moulding; but it is not considered good work.

Fig. 1,432, B,A,A, is also an old bell-pattern angle head, excepting it has a fillet at the top. There are some very good ones at Somerset House, Strand, London. The front is blocked up, and the two ends returned and soldered up the angle A. The shaft (commonly called a socket by most persons out of the trade) is a piece of pipe soldered in the bottom.

Fig. 1,433 is a head fixed in the Strand, London. It bears the date 1777, and the initials of the maker upon it —"H. R. E." The front is blocked up. The ears A, A and back are in one piece, soldered on. Its front is ornamented with a cast head or face.

Fig. 1,434 is a cone head, having flutes at B. It has a pleasing appearance, and is fixed in many places about town, and may be seen round St. Clement's Church, Strand, London. They stand first-rate, and are blocked up and soldered at angle. The ears A, A are soldered on. This kind of head was very common 150 years ago.

On the right is a very pretty hopper head. It is blocked up, then ornamented with the raised half-balls round the hollow, the centre, and abacus. The flutes are wide at top and come to a point. It looks well if made in proportion. It is a very easy head to make.

Before we enter further into the work we should know something about the size of these heads. For this purpose I have drawn Fig. 1,435 to a 1in. scale. This head is

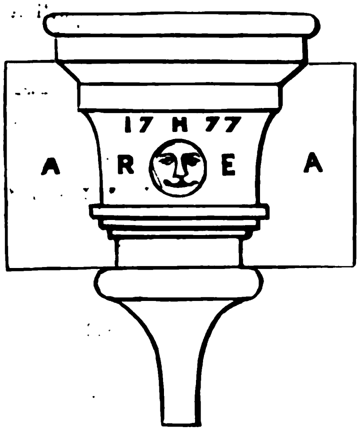


FIG. 1,433.

suitable for a building from 60ft. to 80ft. high, or for the tower of a church steeple, &c. For every additional 20ft. high add $\frac{1}{8}$ to the size. The height is 2ft. 3in., not counting the shaft. Internal width at top, 1ft. 6in. Fillet, 4in. Abacus, 4in. Ovolo, 5in. Annulets, 2in. Colorino, 5in. Astragal, 2in. Hollow, 4in. Bead, 1in. This head is blocked up. Having cut your lead and fastened it on the block, begin with the flapper and well flap it in all over. Then, when your flapper is no longer of use, begin working the bottom mem[illegible] first. Work them step by step.

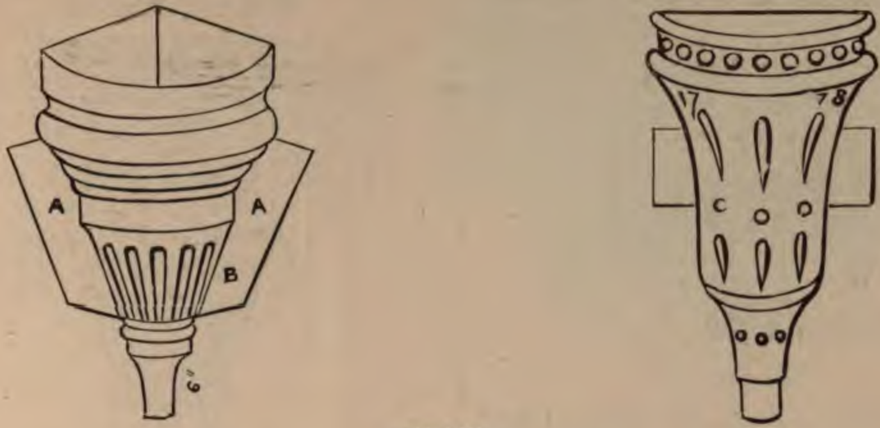


FIG. 1,434.

until you finish, then put the back on and solder up. The ears are now turned back to show about how much lead should show when the head is fixed.

To make up such a head as that shown at Fig. 1,435 in parts, first make the OVOLO, then the ABACUS, and join these together at C. Then make the FILLET to suit the top of the ABACUS, and join this, taking care to have all the corners true and sharp. Next put on the moulding B, which is cast in sand. (Almost any carpenter will get you this moulding in wood for a pattern.)

Now fix the astragal and put on the back. Now fix the BEAD and SHAFT. The wing P, P, may be formed in the back or fixed on after.

Of course any kind of wing, ear or tack may be used to suit the head. Those shown at M, N, being my *registered* pattern, which may be had direct on application, and to various sizes, from all respectable lead merchants.

For the shafts, sockets, tacks, astragals, and other pipe fittings, see Figs. 431, 432, 433, 440, 441, 442, 444, 445, 446, 447, 449, 450, 451, 452, &c., Vol. I.

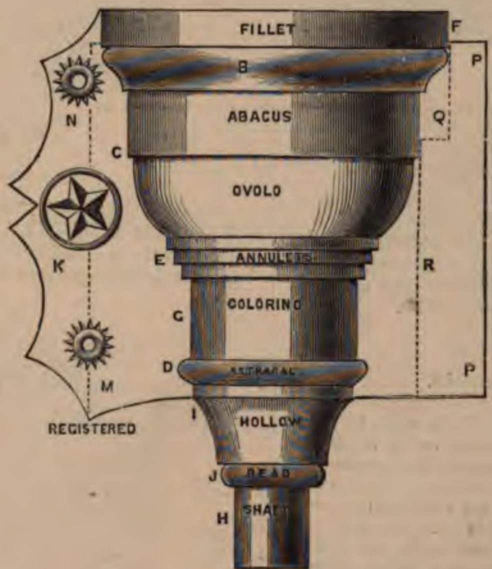


FIG. 1,435.

Now make the COLORINO and the HOLLOW in one piece. Then form the ANNULETS, and fix these either to the ovolo or colorino and join them together.

Fig. 1,436 is the next easy to make, which is made on a block or by-hand—that is, without a block. First take the pattern, for which see my "Geometry for Plumbers."

If a block is used, the members are easily bent to shape of the front. The two sides can be bent on a simple block

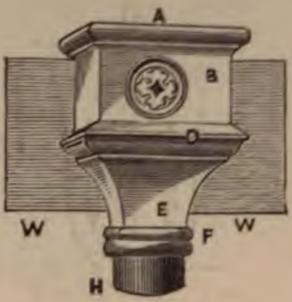


FIG. 1,436.

carved to the shape of front only. The angles are soldered up, and the back and ears in one piece. The flower is cast and stuck on—viz., soldered or burnt on.

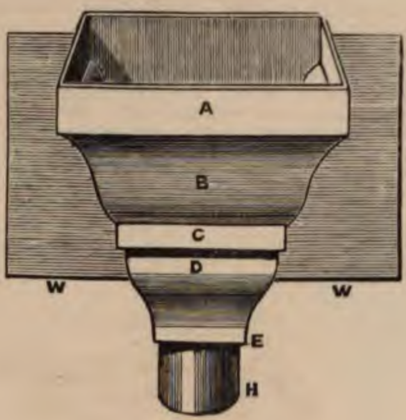


FIG. 1,437.

Fig. 1,437 is made as the former, the difference being the shape. Only the front of this head is to work in with a cornice, the pattern of which can often be had from the mason or plasterer for you to bend your lead to.

The Use of Ornaments.

Fig. 1,438 is very simple to make. It is made by hand without a block, or, of course, quicker on a block, as follows:—Cut 6, A, B in one piece, and bend same into shape. Solder on the sides and backs; put the ears on; then cast the mouldings (which are all soldered on), or if you have a mould you may work this in. Let me here explain that the ornaments on this head are for use as well as to look at. If you examine the top or fillet 6, you will see that it forms an angle and part of a round. (See inside.) The reason of this is clear: it gives strength, and acts as a stiffener to the top of the head. Then look at the ornaments round the front. It is plain that these keep the whole front from bulging. That round B, also answers for this purpose, the same with all the other figures.

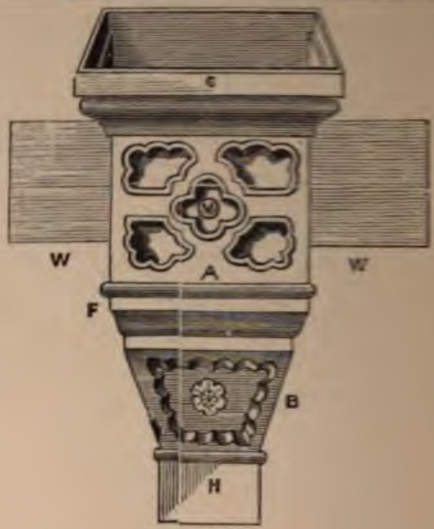


FIG. 1,438.

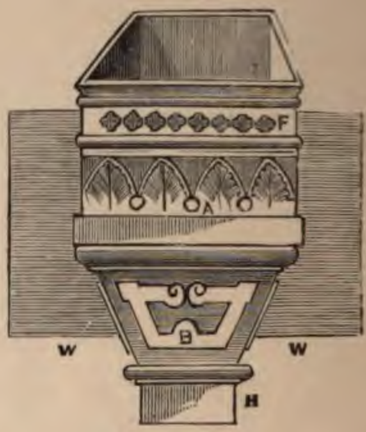


FIG. 1,439.

Fig. 1,439 is made much about the same as the last described, the ornaments F, A, B, being stuck on. This is a very nice-looking piece of work when well carried out.

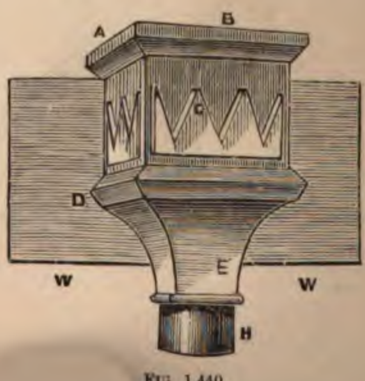


FIG. 1,440.

Fig. 1,440 is made the same as Fig. 1,436, and the ornaments stuck on.

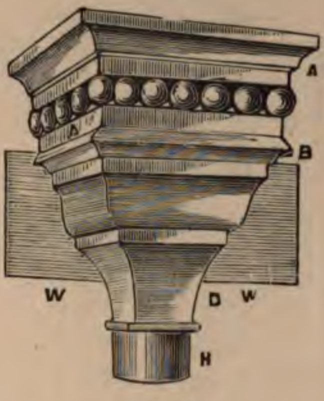


FIG. 1,441.

Fig. 1,441 is blocked up, which requires care, as it easily goes at the corner A, B, which should be padded with wash leather, and worked up with great care. To make this head properly, the stuff should be worked to near about the shape before you block it.

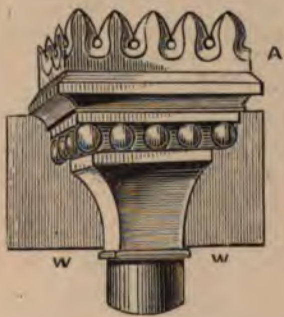


FIG. 1,442.

Fig. 1,442 is made about the same as the last described. Block it up, cast and stick the ornaments on after. This head has a pretty appearance if worked out as shown, and about 18in. to 21in. high for fixing 25ft. high.

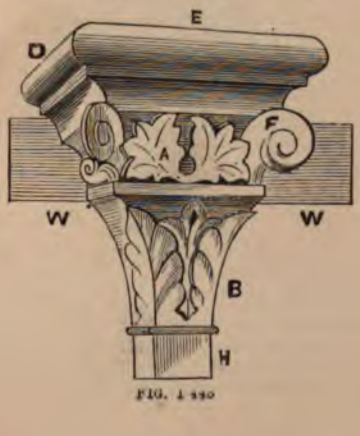


FIG. 1 440

Fig. 1,443 is either burnt or blocked up, and the ornaments stuck on. The leaves B, at bottom, are worked on the block, as also A. Do not turn the sides of the top nosing until after the head is taken off the block. You can then turn it by hand on a piece of roll or mandrel.

Fig. 1,444 is blocked up; but the block must be made a little on the taper to draw at A, A. The twist and ornaments round colorino at F, are cast in the lead or stuck on.

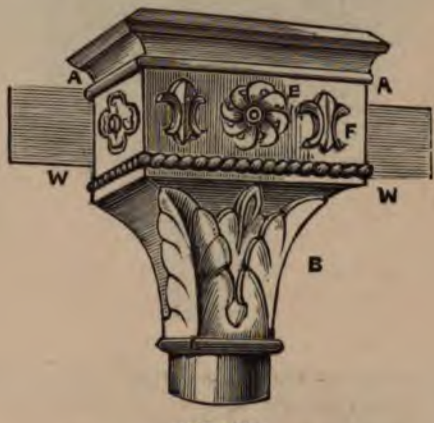


FIG. 1,444.

Work the leaves in the "hollow" B. An astragal looks very well instead of the twist, and is less trouble. Here the back is soldered on after the head is worked up.

In Fig. 1,445 the head may be made off a plain block the shape of front or on a block, the block used only to mark and fix the pieces temporarily for soldering or burning up. This, of course, is done from the inside. The twist and sides may be worked in separate pieces on the front of

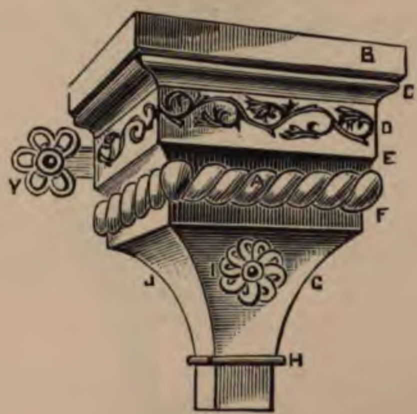


FIG. 1,445

block, but the pattern must not be on the sides of the block. Leave this a plain round, so that you can draw your lead off the block. The scroll work is, in those I made, hand work—but may be cast—also the gun-metal ears or lugs, and soldered on right across the back.

In Fig. 1,446 the head has a lot of work in it, though it looks plain. It may be worked in four pieces, and soldered up, or the front and two sides may be in one piece and the

back soldered on to form the ears. I have made a quantity to the shape of the bottom part up to C, and is a nice little head. Many of these heads may be thus worked

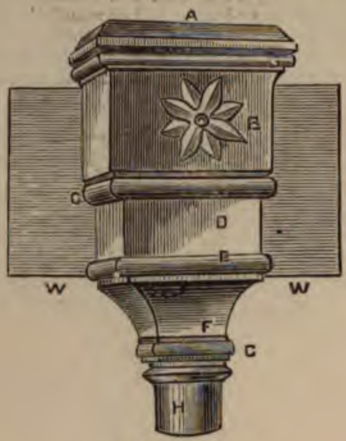


FIG. 1,446.

without departing from the copyright of the article, and I have obtained damages against a person for using these engravings in parts without my sanction.

Fig. 1,447 is a very curious looking head. If you look carefully at it you will see that there are two heads, joined together from the shaft, socket, or spigot. This top, from C, to A, will suit many other figures here shown. It is often made, without a back, to fix on the top of heads to hide the frequently unsightly hole in the wall where the

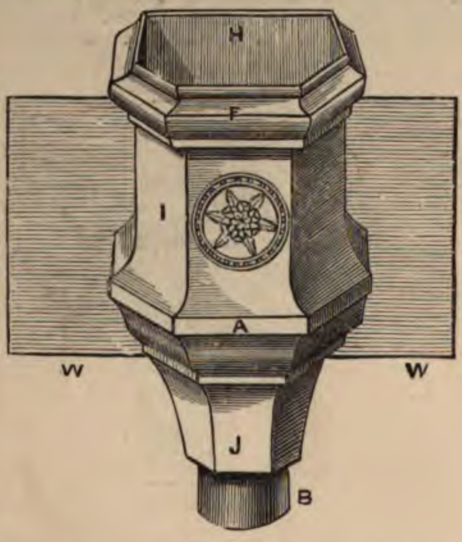


FIG. 1,447.

gutter comes through. Of course that part where the gutter enters the head is cut away. The whole thing may be made in sections or parts, and it may be fixed with ears or with wall-hooks, through the back at H, viz., if the opening above the gutter is not too large. Of course, that is when this top is used separately. The flower is cast and stuck on. The pattern for flower may be worked out at any modeller's.

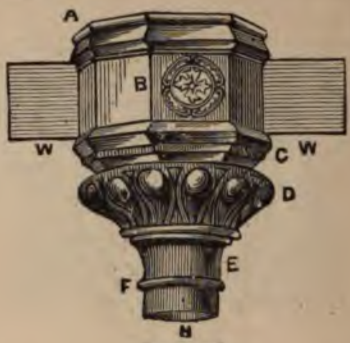


FIG. 1,448.

Fig. 1,448 pattern is made as Fig. 1,447, in sections, or it may be blocked up. The pears are worked on a separate mould and stuck on; also the other ornaments.

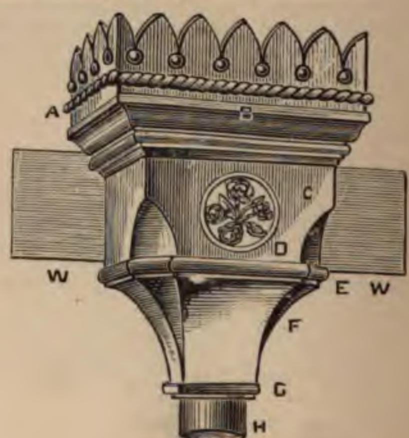


FIG. 1,449.

Fig. 1,449 is made the same as Fig. 1,442; the ornaments are cast and stuck on.

FIG. 1,450.

Fig. 1,450 is a head which I have made hundreds of, and have a mould to cast them. But I shall expect my reader to be able to make them by hand. It is blocked up. The diamond points are cast in lengths and stuck on; also the leaves and half-balls. This head requires a lot of time to

make. I have worked the whole up from one piece of 7lb. lead, excepting the ears, W, W, and leaves, and, if properly done, is a good piece of workmanship.

In this, Fig. 1,451, the plain part of the figure is first (if made by hand) blocked up, the scallop work cut out of stiff lead and stuck on; the half cones, which have to be

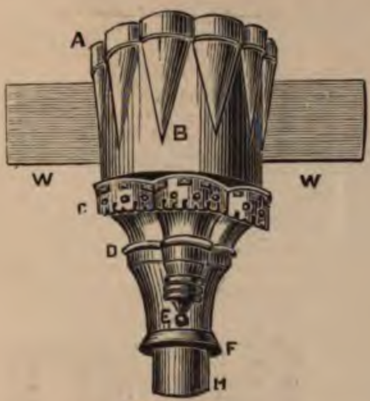


FIG. 1,451.

worked on a block on account of the bead; the cones strengthen it. It is a curious old-looking head, and is suitable for ancient buildings.

In Fig. 1,452 the head is blocked up much about the same as the former. If this is worked on a block see that the flutes are cut so as to allow the lead to be taken off the

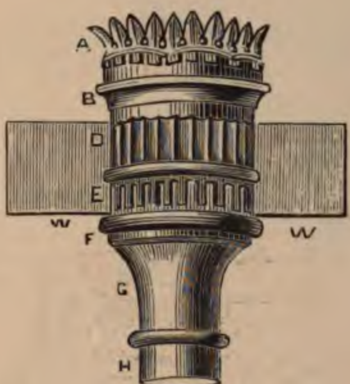


FIG. 1,452.

block from the back, and then a flat back burnt or soldered on. This, if well made, is a very pretty head, and a good finish to ventilating pipes. The fluting should be kept large enough, say not less than 1¼in. for a height of 20ft.

Fig. 1,453 is the Chinese bell pattern. It may be cut off at A, when it makes a very pretty head. Lay a piece of paper over the same at the points, and see how you like it.

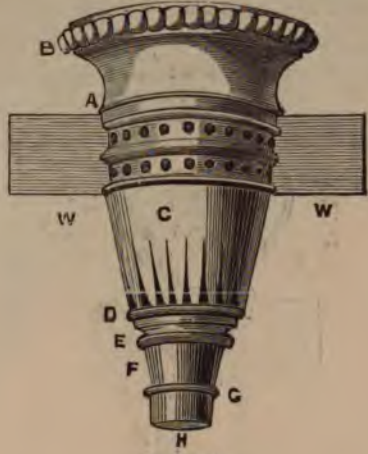


FIG. 1,453.

In Fig. 1,454, although it looks a lot of work, there is scarcely any in it if done the simplest way. If so done, the body is cast in three pieces, besides the back, and burnt or soldered up. It is then as plain as a mallet. If made by hand, it is best made on a block, and all the ornaments

FIG. 1,454.

cast and stuck on; but should you wish to make the whole front and sides in one piece, you can do so as follows:—First, the block must be constructed as follows: the front, up to within an inch of the sides, in one piece. A, is the front carved to the required pattern for casting same.

Fig. 1,455 is a cast head ornamented in front. Of course, being cast, you will at once say that the thing too simple to require any further description. Here becomes a matter of pattern-making and moulding. T head I cast for Messrs. Smeaton & Sons, plumbers, the Examination Schools at Oxford, some years since.

We have now arrived at the acme of rain-water head making. Fig. 1,456, here, is a head, photographed from

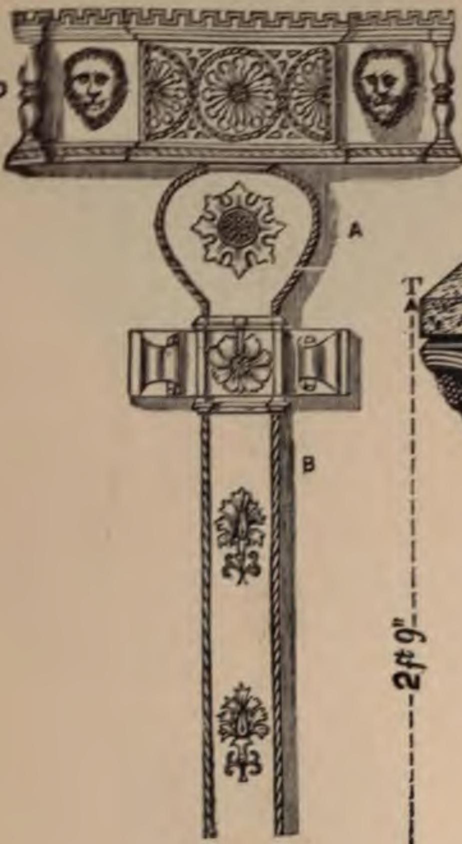


FIG. 1,455

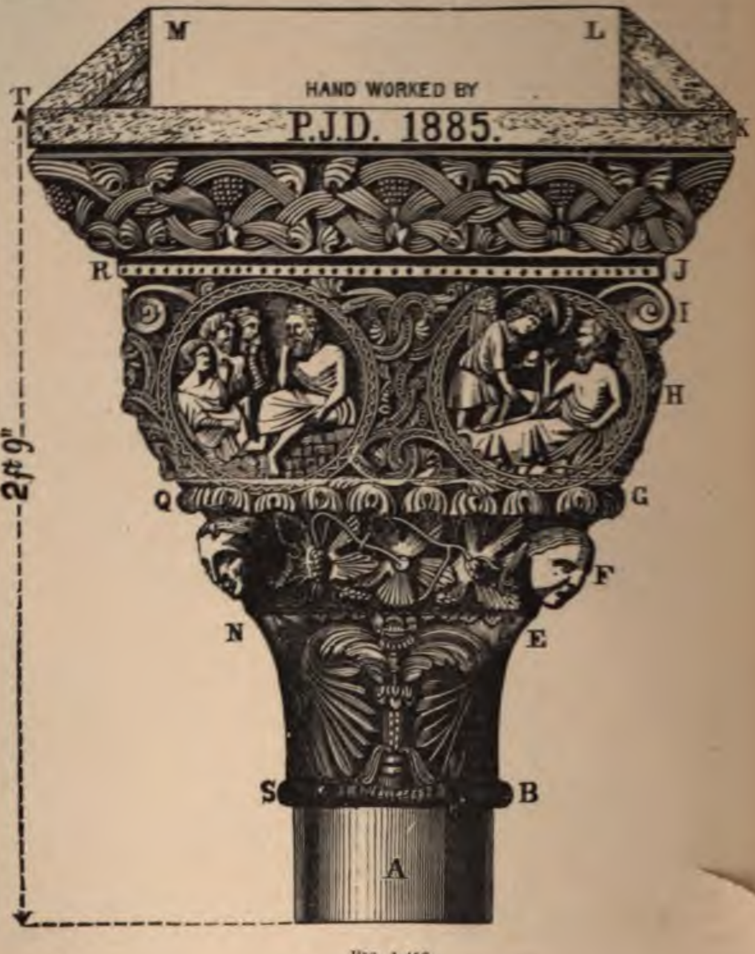


FIG. 1,456.

[illegible] work, a job which I am warranted [illegible] I will give the exact words of [illegible] had it photographed, who was a practical [illegible] of it in our trade journal, *The Plumber* [illegible]

ORNAMENTAL RAIN-WATER HEAD.

[illegible] Earl's Court Road, S.W.

[illegible] illustrates a very elaborately [illegible] and is a thorough masterpiece of lead working by hand; the size of the head is 2ft. 9in. from top to bottom; the front is in two pieces (this should read in one piece) down to S, B, as also the two sides, which are afterwards burnt on at the angles; the back is also burnt on separately, as also the head F. F, (this is wrong, it is in one piece) which act as overflows; R. J, are small lead rivets over a burnt seam, the astragal and outlet are put on separately (no, these are in one piece). There will be three of these heads, one of which is completed. They are being made at a cost of £33 per head, labour only. The work is to be done without solder, and is executed by the hand of Mr. P. J. Davies, and bears his initials and date."

I may remark that each of these heads took me over two months to make, and the first was equal to the third.

FINIALS AND WEATHERCOCKS.

A finial should be useful and ornamental. Its situation is generally on the apex of gables, ridges, and other high parts of roofs, especially in Gothic architecture. It is used to relieve and to give finish to the intersecting points of hips and ridges; it is also used as a lightning conductor, weathercock, &c., &c. Before I proceed to describe the figures, I should remark that the greater part of these are new, and my copyright.

Fig. 1,457 is a part cast lead finial in several pieces. A, and B, should be worked in one piece, C, cast, also D, E cast, F, and the leaves worked up by hand, also the

FIG. 1,457.

ball, and all burned properly at the joints; the bolt not shown goes through the square, F, and through the cross twist, and also B, A, into the base or pedestal woodwork of roof.

Working up a Ball.

First cut the lead the size required, which may be easily got as follows:—Strike a circle the required size from the top of the circle to the bottom, or half the diameter, take the compasses and divide it into as many parts as you can, and then set off as many parts as this along a straight line (this will give you the half-distance round the ball); set your compasses to this, and then strike a circle (this will give you the size for your lead); cut it a little larger to allow for thickening when working over. It is not a bad plan to make it in two halves. For striking this out you only want half the stuff or sized circle. Having cut same, get a mallet and lay the lead on a soft block, and begin hammering away on the inside near about 1in. from the edge; then go round and round it until it is thoroughly hollow; then work it over with the dresser, holding a mallet inside, now and then trying it on the ball. When it is to the shape, solder or burn it up, together with the ball, if one is used inside.

Fig. 1,458 may be either cast or worked up by hand—if by hand, B, and the cone is in one piece, or in four, burned or soldered up. Of course, the former is the best, but if put together in very large pieces, they will stand to be welted or otherwise. If only about 2ft. high and 9in square, put it on in one piece with a well down the back, and work it back to the woodwork. The leaves may be

FIG. 1,458.

worked by hand or cast separately, and soldered to the middle square, A.

Fig. 1,459 is nearly like the last described, the difference being at E; the square is longer, and has a lot of half

FIG. 1,459.

balls bossed up and stuck on, or the whole square and balls may be cast. You can work the lead over F.

FIG. 1,460.

Fig. 1,460.—First cover the base, A, if large, the lead home, then the stem, B, and cover, D;

FIG. 1,461.

FIG. 1,462.

too large, cast this and the leaves or foliage, E, together; the head of the rod is within D.

The block is covered with lead to receive the crown, B, Fig. 1,461, which should be cast lead, having the bolt head therein. The foliage and B, are all cast together quite flat, after which the leaves are bent to the shape shown. Make them strong.

Fig. 1,462 is a lovely looking finial. All the foliage is of cast lead, burned together; the nut of bolt is cast in the box, E, but the head is spike-shaped; the bolt is passed through the square stem, H. This bolt should be copper, and the scroll-work, I, if very fine, should be of copper. The point, J, is also copper. When this passes through the base, A, and through the roof, the copper rod is continued to the earth, when it answers as a first-class lightning conductor.

Fig. 1,463 is made as follows:—A, B, C, is a cone-block; the lead for same is put on, and worked round, having a welt up back; the twist is cast lead; the ball is of wood, covered with lead; on the base of the spike (which is copper) is formed a shoulder, rounded to seat itself upon the top of the ball, so as to shoot the water off the joint part of the ball; the rod runs through the lot, and screws all together, and fixes the whole to the roof; then the lightning conductor is attached.

FIG. 1,463.

FIG. 1,464.

The finial (Fig. 1,464) is part worked and part cast; all the foliage, E, is cast; the spike, S, is copper; the ball is worked on a wood block, wherein is the head of the bolts; the bottom, A, is worked on separately, and the cone, B, if next covered ... either burned or welted; then the bottom end ... red ball, D, is worked down over

K, and also over the top of cone as a lap; then the casting is put on, and screwed down into the top part of the large nut within the ball, and the lightning conductor communicated with.

Fig. 1,465 is a very good finial. Though short, it suits many buildings, especially coachhouses, &c. First cover the wings and square in one piece, take the lead up to E, then cover the ball, and bring the lead down and over the two members below it, with a lap for the neck or cone part; to relieve the blunt appearance of the ball fix a vane on it.

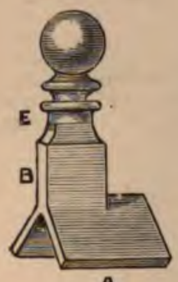


FIG. 1,465.

FIG. 1,466.

Fig. 1,466.—The acorn top finial. First cut your lead for the wings or flashings, A, and work it 2in. up the cone, B; next cover the cone and bring the lead up to the top of the same, and nail all round; next, work a piece of lead to go over acorn and over top balls, &c., so as to work down to the line on the cone at E.

Fig. 1,467.—This is a weather vane, suitable for the top of a finial for a coachhouse or stable; it may be fixed on many of the finials shown in this work.

FIG. 1,467.

FIG. 1,468.

Fig. 1,468 is a very pretty little finial, suitable for dormer tops and turrets; it looks clean and light after it is done.

Fig. 1,469.—This is a finial for the tops of dormers, or the end of a gable roof. First cover the roof part with apron, A, then either boss up the square and cone, B, or

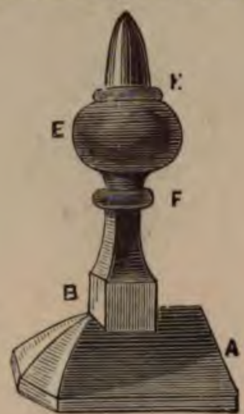


FIG. 1,469.

put it on with a welt—the latter, if time is an object; then cover the ball, E, and bring the lead down over the cone lead at F.

Fig. 1,470.—This finial is a very simple one to cover. First put on the flashing or apron, A, and bring it well

FIG. 1,470.

up the cone, as shown by the dotted lines; I lead on the cone, and work the same well home B, then cover the cone.

Fig. 1,471.—This is a finial for fixing on the centre of a ridge to relieve the long straight line. First fix the flashings next the cone, and bring the same well down on flashing and well worked home. Next cover K, J, H, and

FIG. 1,471.

bring the lead down to F, 2in. below bead, or ring. The feathers are cast and put on last. If the feathers are worked, then make a lead ball and work it downwards to L, and upwards from F, to L.

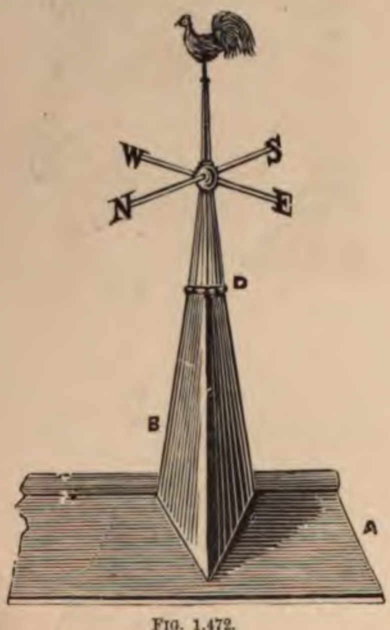


FIG. 1,472.

1,472.—This is another mid-ridge roll finial, having ıercock. First fix the spire-shaped flashings, and ıe lead up cone to apex, and fix vane.

1,473.—First fix the flashing up to B, in one piece, l work it to shape before the slates are fixed; then lift it up for the slater to fix the slates; drop it down on slates, after which cut cone and fix it. Sometimes it is best to have the weathercock or vane standard, D, in a

FIG. 1,473.

long piece, then you may make your roof piece and cone in one.

Fig. 1,474.—This is for a central finial. Here are four parts of a ridge intersecting. This has to be covered in the usual way (see Hips and Ridges). The ridge being covered, next cover the fluted cone, which requires the lead to be in one piece, worked up and properly dressed into the grooves of the cone. Next work up H, to K, and work lead over K, C, and H, in one piece; nail this

above the ring, K. Next work up a piece to the shape of the crowning-piece to fit ball inside of upright scallop work. This ball is covered as those before described, but well work it round with a flapper; the little balls will then

FIG. 1,474.

show through the lead, so that you may see the work; work it then well home, then bring the lead down round D, and over the ring, K; next prepare and fix the cone, G; after this fix the scallop work by burning it on, but leave a bradawl hole in same to let rain-water get clear.

FIG. 1,475.

Fig. 1,475.—This is another finial for the end of a roof. It is made as follows:—The flashings and square are in one piece, E, in another, K, J in another, the plain line, L, and from F, N, to L, in another, the foliage, and sometimes the square, in another. All burnt, if laps are not allowed into one solid piece.

Fig. 1,476.—This is for the end of a ridge; it is a nice finial, and looks well when finished. You may now put the sheet lead all on in one piece, from flashings or skirt,

FIG. 1,476.

FIG. 1,477.

A, to the top ring, B, D; the finial top is all of cast lead, having a rod cast in it about E.

Fig. 1,477.—This is for the top of a pendant-post gable end of roof; the base is covered up to top of standard; B, D, is put on separately, and the last work bolted down through A, B, D. This is exceedingly simple to make; the cone is simply burned up, and the top worked over.

Fig. 1,478.—This is a very heavy finished finial, suitable for the end of a convent roof, it is nearly all cast lead on the outsides; but the block, B, is lined in one piece; the post, G, is best covered with a piece of pipe made to this size; the bevelled ring, G, is in one piece, first bossed up as though you were making a ball, then place it over the woodwork, and work it over G; the feathers or top is cast with the square in one piece, having the head of the nut therein. Next cast the leaves, and fix them round the

bottom of the scrolls, L, the leaves, K, and the leaves, B, when the lot may be bedded on the apron, A, after it is fixed over the tiling or slates, if used.

FIG. 1,478.

Fig. 1,479.—This finial I fixed as a ventilator on the top of a billiard-room; it is very hard to cover, and requires a lot of time. First, fix your pipe, stout 3in. pump, barrel and apron, A, take the lead well up, B, then cut out for the fluted cone, D, and fix it up to that part where the small half balls are fixed at E; work this home. Next cover the part from F, to E, to lap D; next cover from H, to F, then make and fix the half balls. Of course, this finial would be best lined in the shop, with a pipe stem for the ventilator cowl. The ornamental casting on skirt or apron is to keep it down during strong winds. Of course, it also relieves the flat surface of the same. Fig. 1,479A, and Fig. 1,479B, is a section and elevation of a ventilator for soil pipes, &c., and answers as a finial or finish for many places. The section explains the making.

Fig. 1,480.—This finial is for the top of a square cone or rather a pyramid, suitable for a shooting lodge, hut, or stable. A, the apron, B, the cast saw teeth work, C, the base, which should be covered with the top part of apron. ... is best put on in one piece, and worked home with ...nd soft wood tools until nearly finished, then ... box tools. When working in the neck, L, K, be careful and strike the lead so that you do not strain that part round the bevelled ring, H. This is also a ventilator.

FIG. 1,479.

chu...
cros...
whic...

FIG. 1,480.

1,481.

FIG. 1,482.

Fig. 1,482 is covered as Fig. 1,471. The feathers on top are worked or may be cast and stuck on.

Fig. 1,483 being the last of the finials, I have designed it expressly for this purpose; it is suitable for a cone turret or a spire. Begin by putting on the apron, bring the top up to the base-block, B, and nail all round. Next cover the post from the line L, to M, and flap it well all round to get marks; then with soft wood tools work it nearly home, then finish with box tools. Cast M, with a hole through it for rod of weather vane.

FIG. 1,483.

For practice in finial work the following is a good method:—For a few pence you may often buy the old carved legs of furniture, such as piano or bedstead legs. An old stem of a table will serve for a lot of practice. You should also be able to do lead burning.

Also see Ventilators and Cowls.

SINKS.

Anything may be, by some people, thought good enough for a sink, such as a common yard gully, as is shown at Fig. 421, or at the niche sink, Fig. 757. In fact, the name, according to the English language, warrants one in calling anything in the shape of a basin or drain to carry off filth or slops by the name of a sink.

However, I will begin by explaining some of the simplest kind, and explain those which are in general use. We will, therefore, commence at Fig. 340. Here is a stone sink fitted with a trapped waste-pipe, and having a grating soldered down on its top; the gratings are illustrated and explained on pages 133 and 134. This sink waste-pipe should be from 1in. to 2in. in diameter, according to the size of the sink, and having a cone or bell-trap body, as shown at Fig. 298, without the stand-up pipe A, B, for soldering the grating upon, which cone is soldered on the top end of the sink pipe for bedding with Portland cement into the stone sink. See Cementing Sink Pipes to Stone Sinks, page 133.

Vegetable Sink.

This sink is, as its name implies, for washing vegetables, and may be made of slate as shown at Fig. 314, or a small galvanized iron cistern, as at Fig. 1,484, having a grating in the bottom, or a large washer and plug, as at Fig. 298, may be used.

There are various kinds of patented vegetable sinks, one of the best being that shown at Fig. 1,484, right-hand side;

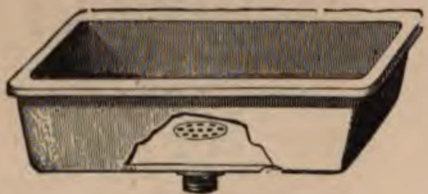


FIG. 1,484.

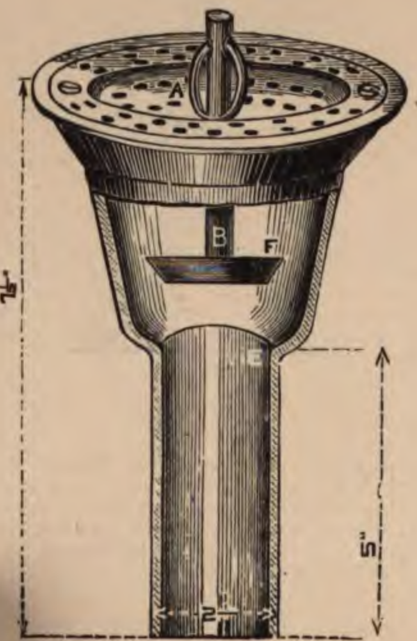


FIG. 1,485.

this sink has the one end partitioned off with a strainer as shown on the right; in the bottom of this partitioned part is fitted the waste-pipe, which is governed by a valve as at Fig. 1,485, fitted on a rod and pull. Of course this sink can be used for other purposes.

Butler's Pantry Sinks.

These sinks are usually made of $1\frac{1}{2}$in. to 2in. wood, and, preferably, lined with stout cast lead. The size generally is from 2ft. to 2ft. 6in. long, 18in. wide, and from 15in. to 18in. deep, with a 2in. or 3in. washer and plug. The best I have seen are shown at Fig. 1,485, because the valve is below a large grating, and can be wiped flush with bottom. The lead should not, under any circumstances, be less than 7lb. lead, 8lb., 9lb., or 10lb. being the usual thing. For lining them, see Cistern Lining.

The taps (see Hot Water Cocks, Figs. 1,667, 1,682, &c.) should be both fixed at one end, having the bosses and pipes by a flanged joint wiped to the end of the sink, and fixed in such a manner that they can be easily turned, the cold water being the first tap from the front. Usually such sinks are provided with left and right handed horizontal cocks, put far enough apart not to cramp the hand. The hot water, of course, in ground-in cocks having a spanner. The top of a butler's pantry sink is usually fitted with a wooden draining board shaped as shown at the housemaid's sink, Fig. 1,486, and a lid or flap to shut the sink down when not in use. The water supply for cramped up or small sinks can be supplied through a swan-neck, as at Fig. 1,667.

Slop and Housemaids' Sinks.

There are a variety of housemaids' sinks, some of a very plain character, simply being a box about 2ft. 6in. to 3ft. long, by 15in. to 18in. in width, and from 6in. to 14in. deep, lined with lead, and having a grating in the bottom near one corner. The sink should be fixed so that it will thoroughly drain itself, and will be all the better if made with a well, about 9in. deeper than the sink, at one end; this allows the girl to throw slops into the well without it getting all over the bottom of the sink. In such cases a draining board, as shown at Messrs. Fell's sinks, Figs. 1,487 and 1,488, may, with advantage, be used for standing the pails upon, which, at any rate, prevents the pails wearing out the lead.

Housemaids' Sinks with Hopper Basins.

Sometimes housemaids' sinks are made as shown at SINK, Fig. 339, with a hopper basin, Fig. 409, fixed into

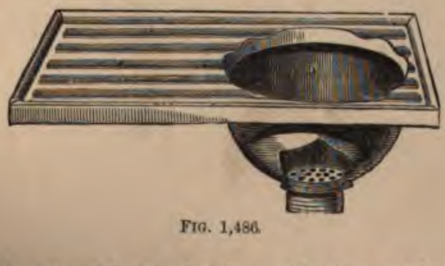


FIG. 1,486.

a well-constructed ʊ, pedestal, or other trap, as shown at 14, 15, 16, Fig. 339. When such are used they should be ...rly supplied with water, and, preferably, discharging ...separate waste-pipe, though not always con-...nd, if not so fixed, should have a non-siphonic trap, as at Fig. 339. It also should have a brass grating with about $\frac{3}{8}$in. or $\frac{1}{4}$in. holes fixed into a cone-shaped piece of lead, and bedded in to nearly the bottom of the basin, as shown at 15, Fig. 339, or the basin may be had with the strainer in the bottom, and is shown at Messrs. Woodward's slop sink, Fig. 1,486, which is a very clean sink, and in every respect perfect from a sanitary point of view.

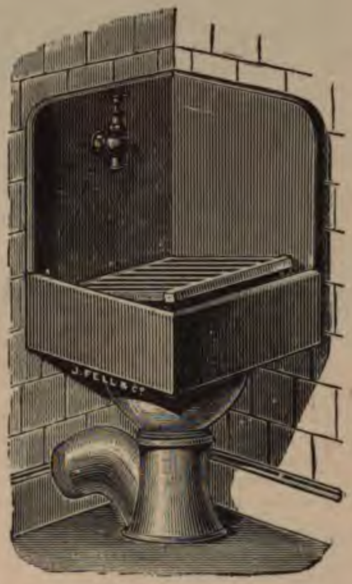


FIG. 1,487.

Angle Sinks.

This is shown at Fig. 1,487, and is very handy for places where room is an object. The sink may be had for screwing on to boards with rounded front.

Slop Sinks (Variety of).

As before said, there are a great variety, even hundreds, of slop sinks made to suit the many requirements of private houses, hospitals, clubs, hotels, and other large institutions; in fact, no one knows the different shapes. Fig. 1,488 illustrates another slop sink, showing the straining boards complete.

Traps for Slop Sinks.

There is a lot of humbug about earthenware trap connections and iron junctions, with abominable patented and useless connections—one day recommended, and the next condemned, by London County Council and vestry sanitary quacks.

I should here remark that although I have shown many of these sinks as I have seen fitted up to a lead or iron soil pipe, I, unhesitatingly, say that I thoroughly condemn any upstairs closet or sink, be it whatever it may, which has an earthenware trap below, entering a lead or iron soil pipe, as the joint to the soil pipe by reason of the hot and

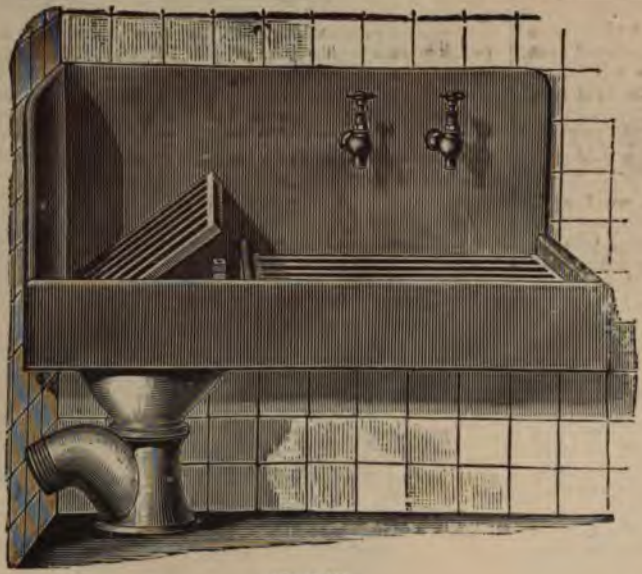


FIG. 1,488.

FIG. 1,489.

cold water being thrown down, causes expansion and contraction, for the joint, however well made at first, stands no length of time. The trap should be of lead, as shown at Foot or Pedestal Lead Traps for Hopper Basins, and as shown in Vol. I., also as shown at Fig. 1,489, which is an almost unsiphonable, and of 14lb., cast in one solid piece, lead foot trap, with flat dip, which may be had of all respectable lead merchants, but be sure and *do not* use on ordinary *drawn* or *round pipe*, as they are next to useless for these cases, owing to siphonage.

Fig. 1,490 illustrates Messrs. Jennings' slop sink with draining board made to work on hinges, which can be lifted up during the pouring of the slops, and let down for the pail to stand upon when drawing water; by this you see that the sink need not be made larger than the slop basin, thus enabling you to fix a slop sink in many cramped up places where you otherwise could not do so, and the draining board being fixed on hinges enables the girl to readily remove it, and adjust the same with the least possible trouble. Of course all these sinks are at times boxed in.

FIG. 1,490.

FIG. 1,491.

Fig. 1,491 illustrates Messrs. Jennings' enamelled slate sink with hinged draining board and hot and cold water cocks complete, as fixed at St. Thomas's Hospital, London.

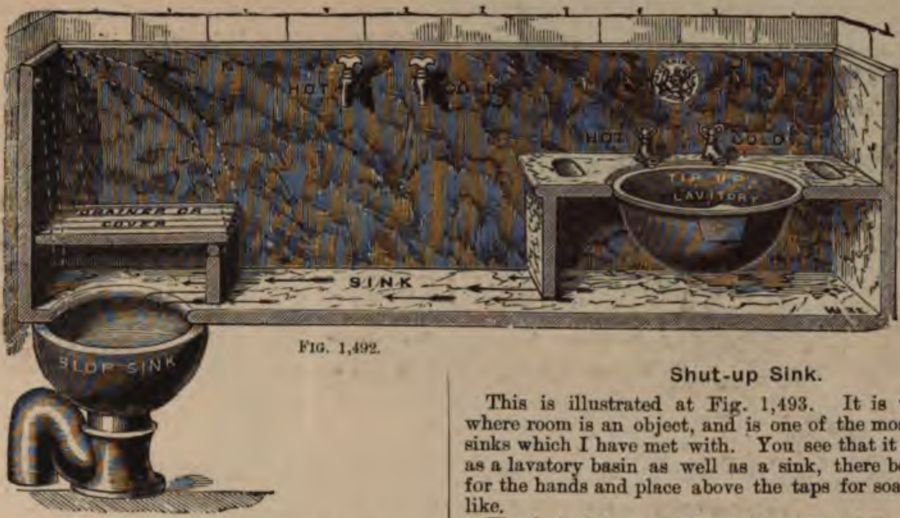


FIG. 1,492.

Sink and Lavatory Basins complete.

Fig. 1,492 illustrates Messrs. Jennings' slop sink and lavatory basin, complete. Here is a much wanted utensil, designed by our celebrated practical sanitarian, the late George Jennings, for the purpose of fostering cleanliness amongst housemaids. Here we have a slop sink, an ordinary sink, and wash-hand basin combined.

FIG. 1,493.

Shut-up Sink.

This is illustrated at Fig. 1,493. It is very handy where room is an object, and is one of the most ingenious sinks which I have met with. You see that it can be used as a lavatory basin as well as a sink, there being a bowl for the hands and place above the taps for soap, and such like.

The first of these were brought out by a fellow workman, the original but now late Wm. Smeaton, who came with me to London thirty-six years ago, and worked together in the plumber's shop of Mr. Wm. Cubitt, builder, Gray's Inn Road, London.

Fig. 1,494 is Messrs. Jennings' patent slop sink with flushing rim and grid. Here the flush rim is supplied

FIG. 1,494.

by a spring valve worked by a lever above the taps, and, altogether, is a very nice sanitary sink, especially for cramped places.

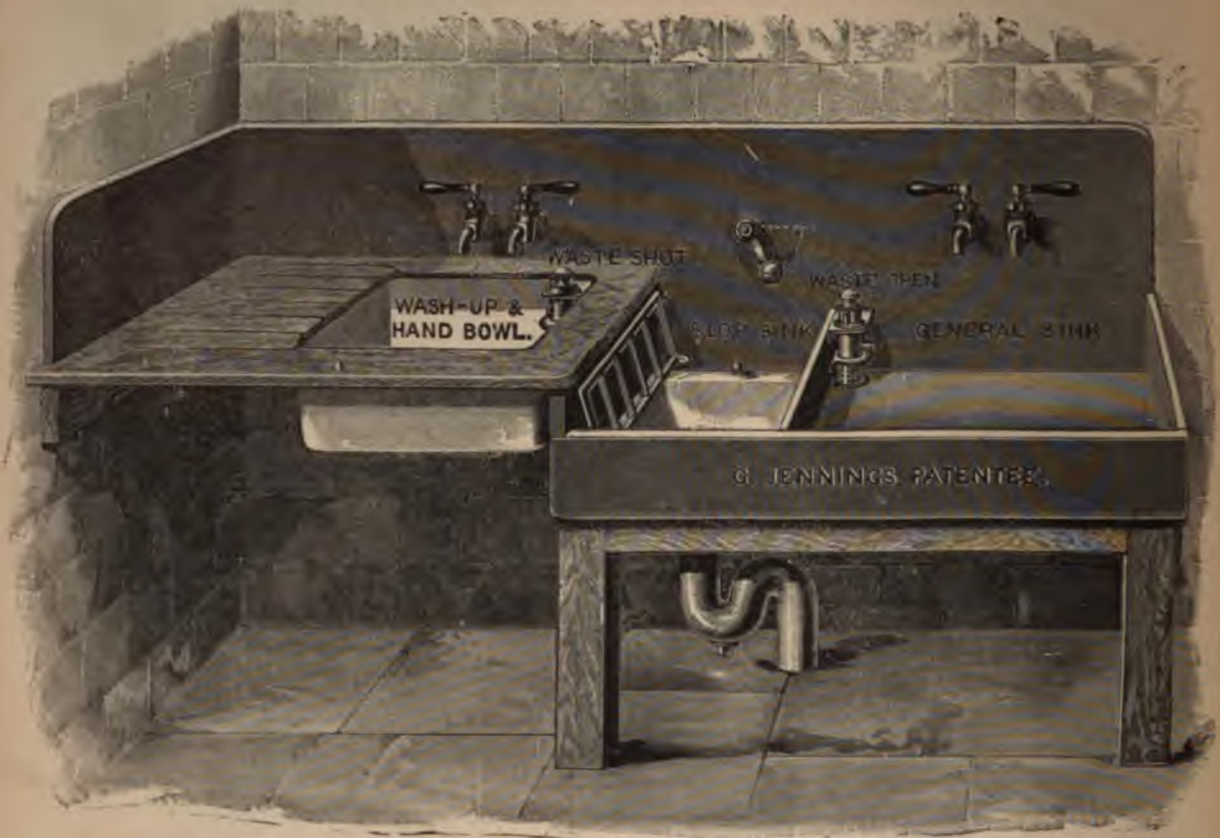


FIG. 1,495.

Fig. 1,495 is Messrs. Jennings' sink arrangement, showing strainer, outlet valves, and will be readily understood by the young plumber. The supply valve to the slop sink is governed by the lever just above, which may be varied to suit circumstances.

Fig. 1,496 is Messrs. Emanuel's glazed earthenware

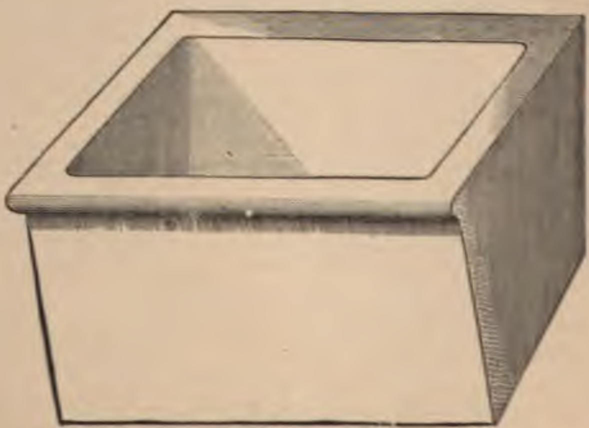


FIG. 1,496

washing sink or tray, which may be fitted with the Royal Palace sink cone and washer and plug, Fig. 1,485, or with

FIG. 1,497.

FIG. 1,498.

the plug and washer, Fig. 1,497 or Fig. 1,498, all of which can be had from Messrs. Emanuel's.

Laundry.

This is shown at Fig. 1,499. A, A, are the trays, generally made of wood, which any good carpenter can make. The joints should be put together with a little white lead and paint, rabbe The cocks, T, may be put together as shown, but long enough to come over the soap shelf, and the shelf should have draining holes and a bead or ledge all round. The cylinder, B, is very handy for heating and storing additional hot water. This is worked by a boiler similar in construction to that shown at 92 E, Fig. 1,565. The cold circulating pipe, R, R, is the cold supply thereto; of course the cylinder has a flow and return pipe, as shown at F, E. The cold water tank, W, of course supplies the trough by way of Q, or the cold water generally. In this system of hot water supply, which I introduced at the Roehampton Convent, about the year 1866, may be seen that it not only affords a requisite supply of hot water to the copper, but also to the

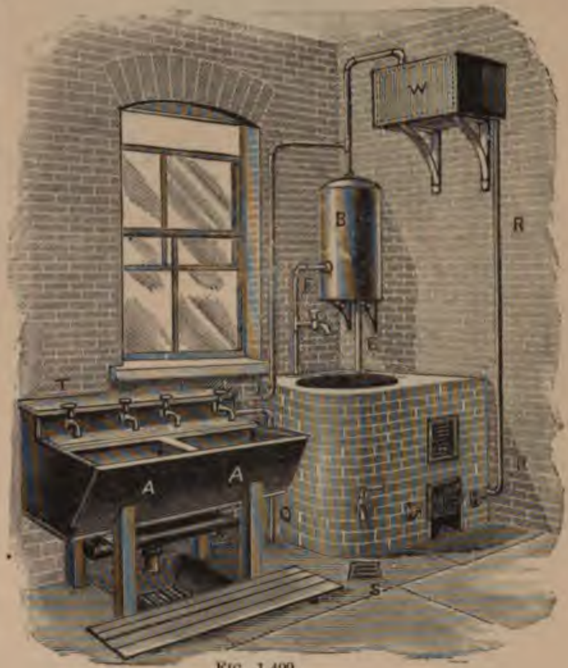


FIG. 1,499.

trays, which is essential for the good colour and purity of the linen; for as soon as your water becomes dirty it can be replaced by drawing from the cylinder, and thus a delay is prevented, which would often otherwise be the case, if such supply had to be taken from the copper, to say nothing of the difference in labour. Sometimes it is necessary to fix a gutter underneath these trays, as shown at X, when there is a quantity of trays in a line. The top of the copper is usually covered with 6lbs. or 7lbs. lead, and to stand up round the brickwork 6in. The turn-down lead round the front of the copper brickwork should turn down about 2in. to 3in.

For drying rooms, see Heating by Hot Water, Fig. 1,712.

LAVATORIES.

Lavatory Basins.

In fitting up lavatories great care should be taken in the selection of suitable fittings for the class of work that has to be executed, not forgetting simplicity of arrangement (see the basins at Figs. 1,500 and 1,501), cleanliness, and

FIG. 1,500.

substantiality of the fittings. Such being the case, I propose to commence by first describing the most simple, and gradually leading my readers, as it were, step by step, to the most elaborate and intricate patterns and systems at present in use. The general height for lavatory basins is 2ft. 6in., and in schools from 2ft. upwards.

FIG. 1,501.

By referring back to Fig. 339, at 19 and 20, the reader will see a simple snug lavatory basin suitable for its situation and work. All that is required is a round basin 13in. or 14in. in diameter, as shown at Figs. 1,500 and 1,501, the latter having an overflow arm. This basin is shown fixed at 19, Fig. 339, simply having a washer and plug in the bottom, and an overflow arm for the overflow pipe 23, Fig. 339, which may be branched into the waste pipe as shown at 22. Below the basin should be fixed some kind of trap, having a cleansing cap and screw, as shown at 22. From the top of the trap should be taken an air pipe, as shown at 24, and carried up, as shown at 25, to prevent siphonage and corrosion, or into a non-siphonic trap, or the outgo of the trap L, W, may discharge into a properly constructed open trap head, as shown at L, Fig. 354, Vol. I., or otherwise. But in this case it is branched into W (waste) pipe, as shown at 37, Fig. 339. Should the expense of carrying up an extra vent pipe be too great, it is possible that this pipe may be taken back and branched into the main waste pipe at about 33, and if this is too much trouble use a thoroughly well-constructed open top trap on the inlet end of the waste pipe or a proper D trap, as shown at the lavatory basin, Fig. 340. It should be remembered that I am not bigoted or always in favour of the D trap, but ever prefer to have them properly ventilated, but circumstances will not always allow of this. I mention this to prevent any quibbling, and to show that I am quite *aware that in certain* situations an S trap will answer every purpose. It is under such circumstances that the plumber must exercise his own judgment or discretion. By again referring to Fig. 340, it may be seen that this basin has an additional fitting. Instead of the simple washer and plug, as fitted in the basin Fig. 339, it has a pull up quick waste, as exemplified at H, Fig. 1,502. It will also be noticed that to the waste pipe from the trap, Fig. 340, there is no vent pipe, but the end of this waste pipe is taken right away to the gully trap, shown in the left-hand corner of Fig. 340; or, if the circumstances will allow, it may be taken to the fresh air inlet part of the main in the right-hand corner of the Fig. 340 as the sink pipe does. But under these circumstances do not branch the lavatory or other waste pipes into the waste pipe of the bath, simply because, by so doing, you are very likely to interfere with the draught of the bath waste, and so cause it to run sluggishly and noisily. And further, it is a matter of very common occurrence for the bath pipe water, by its induced action, to empty the other traps, more especially if the trap is not of the D pattern or kind, having an exceedingly small inlet or dip pipe in proportion to the body.

In order to prevent siphonage, I have fitted a 3in. wide and 6in. deep D trap, with an only 1¼in. dip pipe, and found it to effectually prevent siphonage under the most trying circumstances. Having settled about the basin, waste pipe, and class of trap, the next thing for consideration will be the outlet. The washer and plug is known to

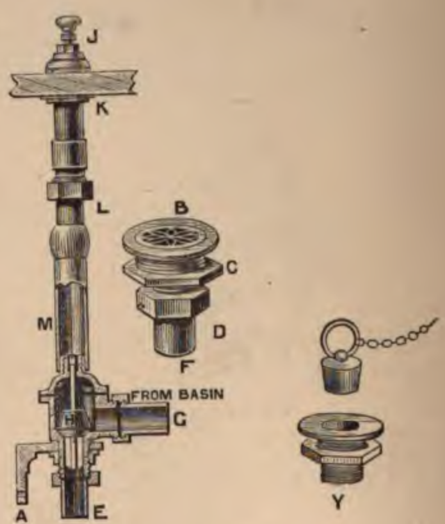


FIG. 1,502.

all plumbers, therefore let us next examine Fig. 1,502. Quick waste A, is a bracket to be fixed to a wooden block to the brickwork or otherwise. B, the union for fixing with a leather washer on the *inside* of the basin. This union has a fly nut C, for holding the union firmly to the basin. The union may with white lead be bedded to the basin. Y, is the washer [illegible] which is ground in or covered with

rubber. F, is a lining for soldering or connecting to a short length of leaden pipe, so as to connect it with the lining G, of the valve. H, the outlet valve. E, the lining leading to the trap. J, the pull-up knob, fixed by the fly nut K, to the slab or top. L, the deep nut or lining for connecting the stand pipe M, or valve with the pull, which may be done with copper wire chain or otherwise. It will readily be seen that with such valve arrangement as this there is not any provision for overflow, and therefore an overflow arm must be fixed on the side of the basin, as

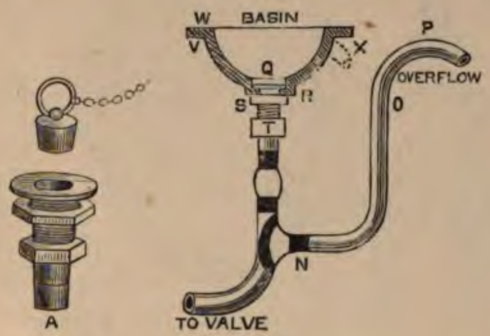


FIG. 1,503.

shown in the dotted lines X, Fig. 1,503, or a branch inserted into the pipe, fixed between the valve and washer A, in basin as at N, Fig. 1,503, and in such a manner that the pipe O, may be taken or bent up to the water level of the basin, as shown at OVERFLOW, and having an outlet to dicharge either into the open air or otherwise, as discretion or circumstances may dictate, taking care at the same time that this pipe does not siphon out of the basin. If the outlet of this pipe has to be taken down below the top or water level, an air pipe should be branched into the top at P, which will, of course, stop siphonage. Within the last few years the standing waste pipe, so well known in connection with cistern work, has been introduced for the outlet valve, which will be easily understood on examination of the diagram, Fig. 1,504. Suppose the washer A, to be fixed to the bottom of the basin, and the union bend D, to be attached to the body X, water from within the basin can run down through the union and charge the body up to the top of the stand pipe Z, and overflow, as shown by the arrows, so that it would be impossible for the basin to overflow, assuming always that the overflow is large enough. Next, by the knob M, and rod L, pull up the stand pipe Z. By so doing the valve F, must also be opened, which allows the contents of the basin to run full pipe bore away. But suppose you let go the knob before the basin is emptied (say when half empty), unless you have a good air pipe or a properly constructed ᑌ trap to allow plenty of fresh air, the seal of your trap will be instantly destroyed, and the stink arise through the standing waste. There is, however, a remedy which I have invented and put into practice. It is as follows:—Fix an inverted cup on the rod L, so that its mouth or lip shall cover the standing waste pipe, when the knob is let go in a similar way that the bell trap does, but let it dip to about the bottom of the basin. More will be said about this diagram in Water Supply, as also in chapters on Bath Work.

It frequently occurs that the wastes of lavatories are fitted to work with a kind of stool valve, as shown at Fig. 529, with levers and chain connected to the ordinary pull. When such valves as these are fitted, make the ordinary outlet B, Fig. 1,504, the inlet from the basin, so that all the water from the basin may drain entirely away, and see also that the rubber on the valve is properly fixed with a pill-box lid nut G, Fig. 1,505, which will prevent the rush of water having effect upon the edges of the

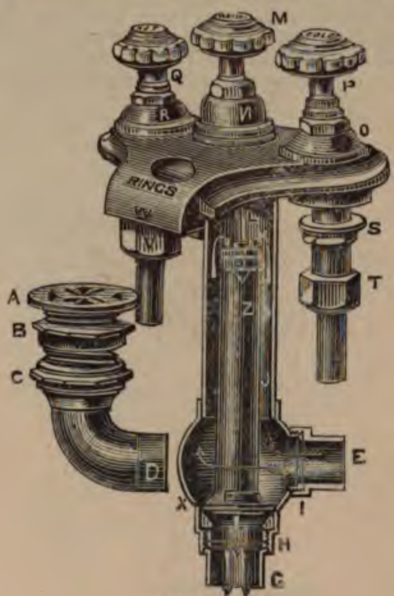


FIG. 1,504.

rubber, which otherwise will have a tendency to pass into the seating. As a matter of course, when the rubber is fixed to the valve in this manner, the seating must be a

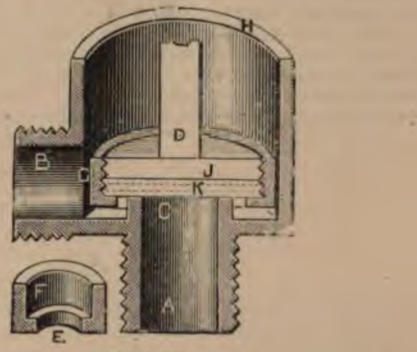


FIG. 1,505.

raised one, as shown at C, Fig. 1,505, &c. This raised seating is to allow for the bottom part of the pill-box nut, which otherwise would prevent the valve from closing, unless a washer were fixed round the seating.

Water Supply to Lavatories. (Fig. 1,506.)

There are many different methods whereby the water supply can be accomplished, some of which are of the most intricate nature. I shall, however, be content to describe some of the more simple ones that I have fitted up myself. Fig. 1,506 is a very good lavatory, similar to one that I fitted up in Portman Square twenty-eight years ago, and, moreover,

one not likely to get out of order. A, is an 18in. white and gold basin, with inlet fan B, from hot and cold supply valves. E, is the overflow pipe brought from the arm of the basin into the heel of the U trap. F, is the quick waste constructed in the dip of the U trap, the valve being a 2in. ground-in long pump spindle valve, worked by the use of a rod and sling attached to the pull-up knob "WASTE." The levers of the hot and cold supply are attached to the

FIG. 1,506.

knobs by the use of the chain G, H. Of course, the pulls are made in such a manner that by giving them a quarter turn they will hang up. To this basin is fixed the swing pillar-bracket L, which is used for shampooing &c. If the arm N, is made straight with a universal joint—viz., double that joint shown between L,N, and fitted with a small jet, the ears may be washed out, &c., &c. The pillar is fixed to the marble slab by means of a fly nut, as shown. The

FIG. 1,507.

swan neck may be fitted with universal joint, or sometimes only made to swing in a side direction, or it may be fitted with indiarubber tubing. The valve L, may be dispensed with, and a double valve, one for hot the other for cold, with a mixing chamber for the hot and cold water. Or it may be supplied through a breeching piece, as shown in Fig. 1,507.

FIG. 1,508.

Fig. 1,508 illustrates one of Messrs. Fell's shampooing tubes, valves, and rose. It clearly illustrates the method of fixing by fly nuts to the top of the slab.


FIG. 1,509.

Fig. 1,509 illustrates the valves and breeching, also the hose union ribbed for holding the pipe.

Next examine Fig. 1,510. This is a very handsome lavatory arrangement. The valves are shown fixed, and are of the lever kind, fitted as in Fig. 1,506, excepting that the pull arrangement is of the crank kind (see D, Fig. 1,510). This crank is also shown fixed n the skirting at E, F, G, and is supposed to be attached to the ends of the lever. H, is the washer for fixing into the bottom of the basin, as at Q, Fig. 1,503. J, is the straight hunch trap, shown and described in Fig. 216. Great care must be taken to fix a proper size air or vent pipe at VENT to such

a waste pipe. The water is, in this diagram, supplied through a lion head inlet spout, but is not nearly so good as that shown in Fig. 1,506. The overflow holes are shown at B, and a separate pipe, I, taken right away to discharge

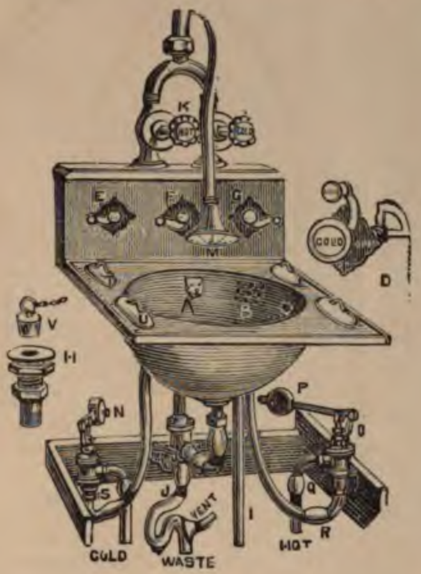


FIG. 1,510.

over an open head or otherwise. K, is the hot water valve for hand washing or shampooing. On the other side is L, the cold. Both of these valves are connected to the breeching piece, and by indiarubber tube to the rose or jet.

FIG. 1,511.

Fig. 1,511 is an angular lavatory basin, showing the arrangement of pipes, valves, &c., together with breeching piece and union, as at the left-hand side of the figure at ARM, HOT and COLD. It also illustrates the leaden breeching piece on the right-hand side at COLD. The hot water may flow up the pipe at A, whilst the cold may enter at COLD, and from there by the pipe B, to the arm of the basin, and out at the shell inlet D, which washes down the basin and so keeps it clean, There is a new arrangement added to this lavatory basin—the distilled water pillar. This is supplied through a tin pipe.

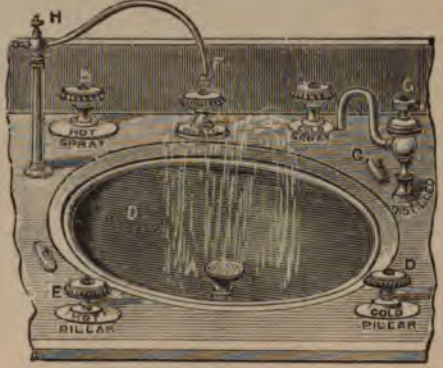


FIG. 1,512.

Fig. 1,512 illustrates the top part of a very beautiful lavatory, having some additional work. This has the usual waste pipe, as at Fig. 1,504 (see waste pull, Fig. 1,512). It also has screw down valves fitted below the slab instead of the lever arrangement. The reason for the employment of these screw down valves is that they may be adjusted to any pressure, so that the water may fountain or spray up at any required temperature or force. A shampooing-pillar H, is also provided with rubber tube and rose, which can be attached at a minute's notice, and in such a manner that both hands are at liberty to wash, &c. There is also a pillar G, for filtered or distilled water. Sometimes a rubber hose and jet is fixed to these pillars, &c., for producing a jet to wash out the ears, nose, or mouth.

Cabinet Lavatories.

Fig. 1,513 illustrates a very handsome cabinet lavatory basin as made by Messrs. Fell, and is a very good specimen of what plumbers can get up. It is supplied with hot and cold water and a quick waste valve, as at Fig. 1,504. The earthenware or basin can be had from Messrs. Twyford, should you have to repair or replace one.

Fig. 1,514 is rather an elegant dressing room lavatory sold by Messrs. T. & W. Farmiloe, and has one or two minor points to notice. First, the soap dish is raised so that the water does not saturate the soap, and also drains away from the underside of the brush dish, without fear of these dish pipes becoming blocked or choked up.

It is also fitted with swan necked universal joint, as at D, Figs. 905, 906, and 1,523, &c.; jointed shampooing apparatus, with reversible rose and douche jet for delivering hot, cold, or tepid water. The basin here is a tip-up one, but, of course, any basin may be used.

The mirror may be of any class, but the one shown here has bevelled edges. A suitable wood is walnut with Belgian marble.

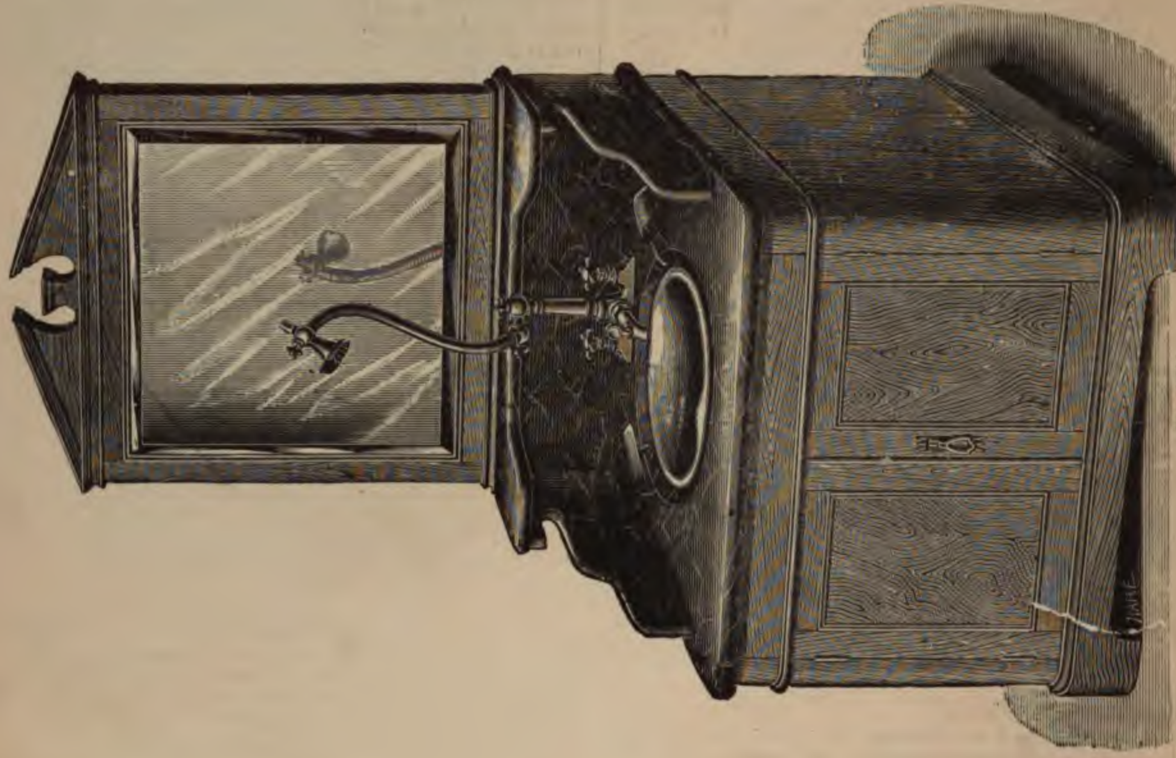


FIG. 1,514.

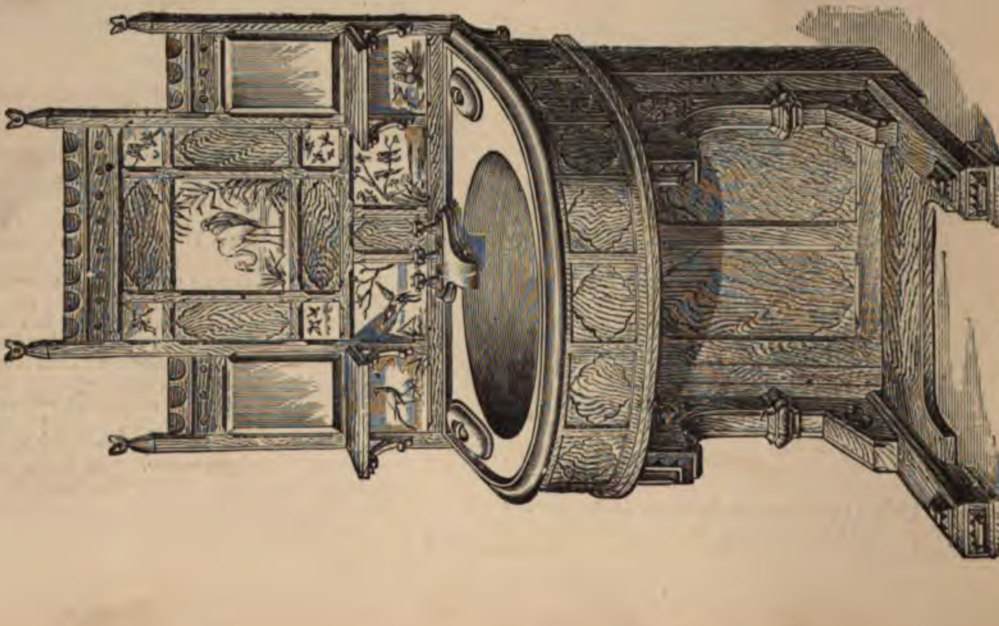


FIG. 1,513.

FIG. 1,515.

Fig. 1,515 is a very neat little cabinet washstand, suitable for a bedroom, as is also Fig. 1,516. The one on the left being a lavatory and slop sink combined.

Fig. 1,517 is a lavatory suitable for an entrance room or passage to a w.c., sold by Messrs. T. & W. Farmiloe. It has, as can be seen, a raised rib or bead all round the front, and is fitted with hand swilling rose. The basin may be of that shape shown at Fig. 1,518, which is an end view of Messrs. Emanuel's registered—but is shown in Fig. 1,517—is D shape, and altogether is a very nice compact piece of workmanship.

FIG. 1,516.

FIG. 1,517.

FIG. 1,519.

washer and waste being also shown at Fig. 1,519, but in this case a ground plug with ring is shown.

FIG. 1,520.

FIG. 1,521.

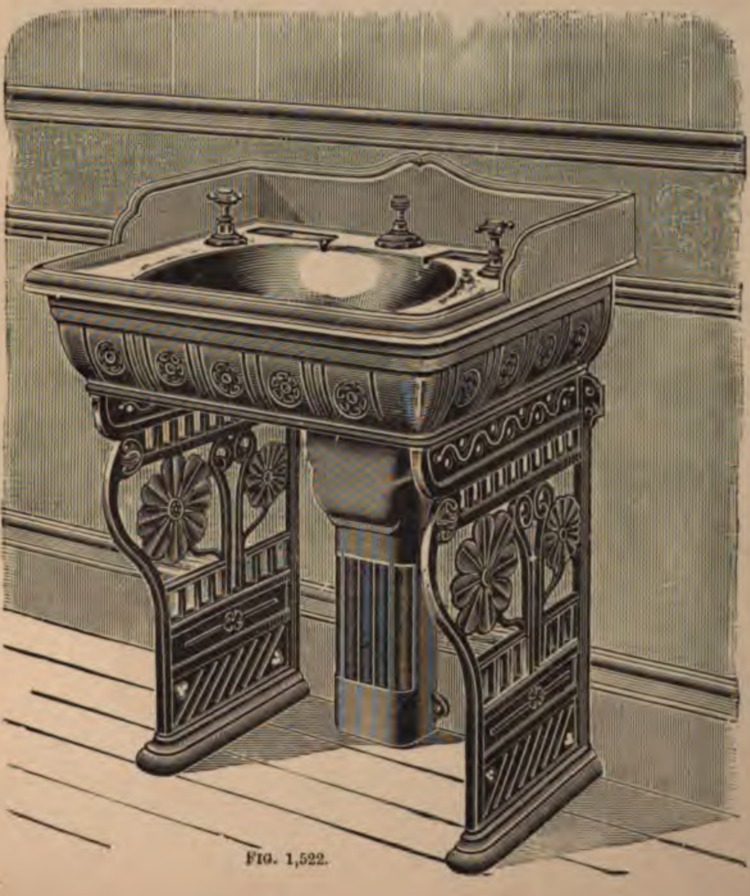


FIG. 1,522.

Fig. 1,520 is a half pedestal lavatory basin, with bottle waste and overflow trap, for fixing against a side wall of a closet, and Fig. 1,521 is the same, but for angles. The standing waste and overflow in these are similar in construction to Fig. 1,518, and may be had from Messrs. T. and W. Farmiloe. For these pillars also see Figs. 1,538 and 1,539.

Fig. 1,522 is a very nice lavatory basin on cast iron stand, with D shaped basin. These D shaped basins are an improvement on the round or oval basins, inasmuch as you can turn up your shirt sleeves and go in for a good swill without fear of the water running down at your elbows and on the floor, as can be seen; and the frame being made principally of cast iron and a trap and pipe shield at the back, is not likely to be tampered with by children, and is, therefore applicable for schools, &c.

Fig. 1,523 illustrates the lavatory fittings. This ingenious arrangement, besides combining the ordinary lavatory supply, has all the convenience of the ordinary shampooing valves, indiarubber tube, and rose, without their disadvantages. The double joint renders the manipulation of the shower douche or spray, by the user, as easy as a flexible tube. The swan neck being self-supporting in any position, both hands are at liberty; while the various parts being rigid, the accidental breakage of toilet basin, due to the use of flexible tubes in connection with lavatory apparatus, is entirely avoided.

Fig. 1,524 illustrates gauge cocks with spanners, for adjusting the inflow of hot and cold water to lavatories, baths, &c.

FIG. 1,523.

FIG. 1,525.

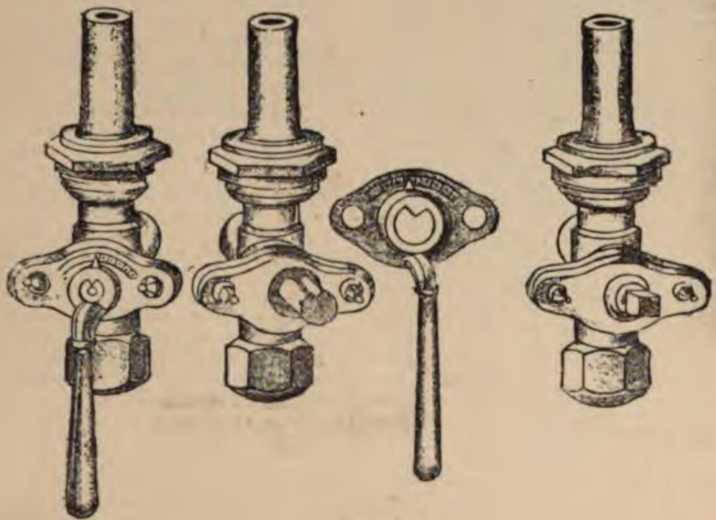


FIG. 1,524.

Cabinet Lavatories with Bidets.

Here is illustrated at Fig. 1,525 a cabinet lavatory and bidets. These bidets are made to run in and out upon runners and telescopes, and supplied with water from the different pulls and telescopic pipes for wastes with water supplies through sliding or telescope tubes working through a stuffing box, or suitable cup leathers, &c., similar to the piston of the plumber's force pump.

Cabinet Lavatories with Bidets and Urinals.

Sometimes these cabinet lavatories are made with swinging urinals, as shown at A, Fig. 1,525B, at other times with

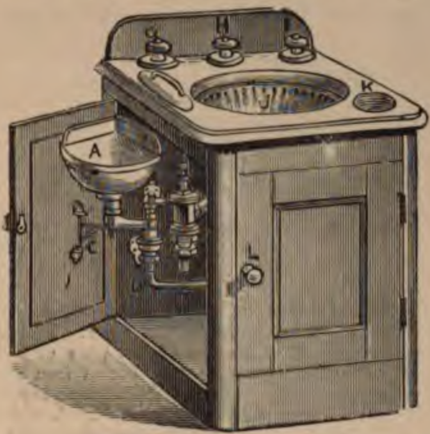


FIG. 1,525B.

a bidet on one side and urinal on the other. For bidet also see Figs. 1,661 and 1,662.

FIG. 1,526.

Fig. 1,526 illustrates a
basin, with basin and skirti
simple, is, when supplied
fixed through the skirtings
and most sanitary lavator
a sanitary point of view, is

tip-up yet in the market; as whatever filth is put into the basin it passes direct into the waste pipe and is done with, which is not the case with tip-up arrangements, because in tip-up basins you must have a kind of dirt container, and which is invariably dirty after use for a few weeks—aye, days.

Valves and Water Supply to Lavatory Basins.

We have seen some of the most elaborate cabinet lavatories, but very little has been said with regard to their water supply, we will therefore go back to Fig. 1,512, and further examine the jet supply illustrated at A. In this diagram the hot and cold water supply valves are fixed below, and branched one into the other, so as to allow the water to come up a small pipe, fixed *inside* the waste-pipe, but quite separate from the waste-pipe and from each other.

As you are aware by this time, there are many different kinds of valves suitable for this class of work, which may be seen in the earlier and latter parts of this work, especially at Figs. 1,506, 1,510, 1,511, &c., which you should be thoroughly familiar with. The diagrams, Figs. 1,506, 1,510, 1,511, and 1,512, will illustrate the method of fixing as done at least thirty or forty years ago, and, to this day, cannot be beaten; although we hear so much of the so-called sanitary improvements by which the real plumber is losing his individuality, by allowing himself to be led away in listening to the whimsical fads of the speculative, non-practical, though would-be sanitarian (including house agents), who have the tongue and brains only for chattering to foolish and timid doctor-scared householders.

These men are for ever on the alert to introduce something they think they can palm off as new, in order that they may get an introduction into a substantial plumber's establishment, often ousting those good and well-tried old wares, such as the renowned valve closet, and such-like, for some gingerbread rubbish with taking or gilded appearance; and if they cannot get a line, as they call it, they do not scruple to hurl their wares into the office of the above self-made and other *certificated* sanitary quacks, who, of course, take large commissions for the introduction of such rubbish into their specifications, or, where they cannot brazen this out, they say we do not recommend any particular article, but, like foxes, take good care to look after themselves and their fancy-paying speculative gentlemen by quietly introducing the article through the medium of a highly worded circular. And it is these insignificant looking, though gigantic frauds, practised from the four quarters of the so-called sanitary circle, to the great detriment of the real practical plumber, which I always have and always shall try my level best (by my writings to train young plumbers) to exterminate.

FIG. 1,527

nd 1,528. The
dirt and bits of

stuff passing through the pipes, and are all right for high pressure work. This valve is of the ordinary loose valve stop-cock kind, fitted with hot-water rubbers and unions, as shown at A, B, Fig. 1,527, or the valves may be of the Shank's, Fell's, or other makers' box pattern, for fixing

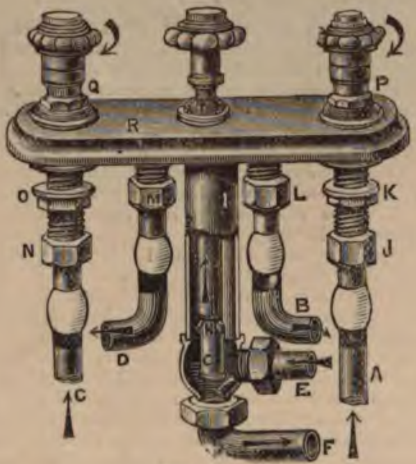


FIG. 1,528.

upon the slab, as illustrated at Fig. 1,528. A, is the cold inlet; B, the outlet, which may be taken to the arm of the basin or to the bottom, as in Fig. 1,512; C, is the hot inlet; D, the outlet, which can be branched into the pipe B; or, as

FIG. 1,529.

FIG. 1,530.

is now the case, be taken separately into the basin. Figs. 1,529 and 1,530 illustrate the valves at times used at hot pillar and cold pillar in Fig. 1,512; Fig. 1,530 having a simple flange for screwing to woodwork, whilst Fig. 1,529 has a screw and fly nut for fixing to marble tops, &c.

Bath Cocks.

Some plumbers have an objection to the use of valves, especially for hot water. Where this is the case, a good ground-in gun-metal cock must be used, preferably of the gland kind, Fig. 1,633, which, under certain circumstances,

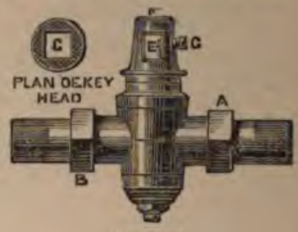


FIG. 1,531.

is far the best. Such a cock without gland, and to work with levers, &c., is illustrated at Fig. 1,531. This is fitted with union A, and B. The top of the plug or key has a square hole cored in, so that a square bar of iron will turn the plug or key, instead of having the cock-key K, Fig. 1,532. When the cock-plug has a square head, and the key K, Fig. 1,532 has to be used, take care that the rod of the

FIG. 1,532.

key is not made too long, to ride upon the plug of the cock, for, if allowed to do so, it will not only work stiffly, but be apt to jam, so that it cannot be moved to turn the hot-water off or on. Many bath cocks work stiffly on this account. The lever part of the key is shown at B; A, is the plate for fixing on S, the part to shut on to the key K. Occasionally, plumbers will use a three or four-way cock for the hot and cold supply to lavatory basins, such as shown at Figs. 1,533 and 1,534. When this latter description of cock is

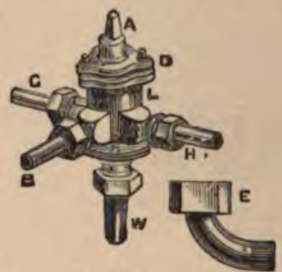


FIG. 1,533.

FIG. 1,534.

used, caution must be exercised to fix a safe under the plugs, as, in a very short time, especially if working under a high pressure, they are sure to leak, owing to the sudden expansion and contraction of the metal, by reason of the

rapid change of temperature caused by the hot or cold water. Another evil will be found with gland cocks if they are not made properly, that is with the packing. This is apt to be screwed down too tight, thereby jamming the key so that it cannot be turned. This is owing to the packing pressing upon the set-off or shoulder on the key, instead of being made to press upon a washer fixed upon the shell of the cock, and in such a manner that it will only press laterally upon the spindle part of the key. It should be remarked that many "cockeys" (cock makers) call a cock-plug a key (K, Fig. 1,532 is a key), while other firms call it a socket key, and the handle B is called a lever, cock-lever, bath-handle, &c., &c.

Fig. 1,535 is a lever having a pointer for indexing when the cock is open, shut, &c., and used for a three or four-way cock, Figs. 1,533 and 1,534.

FIG. 1,535.

Fig. 1,536 illustrates a pull for screwing to the slab or top of the lavatory; A, shows it when turned round and

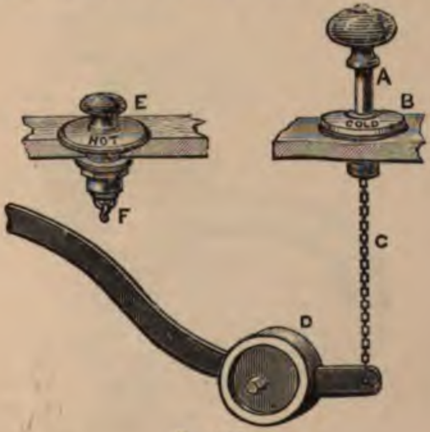


FIG. 1,536.

held up. This is done by a small pin working within a slot. I, J, H, Fig. 1,537, illustrates the pull and the fly-nut G, separately.

Fig. 1,537A illustrates the lavatory basin-waste, which will also work for the supply valve as fixed upon a bracket, also illustrated, but fixed at M, L, Fig. 1,511. In Fig. 1,537A the adjusting holes can be seen at S, W, H, R; the rocking standard G, and the stuffing-box on the top, are also plainly shown. To take this valve to pieces, first take out the cotter-pin from the spindle at X, then the rocking standard cotter-pin at G; if you take out the

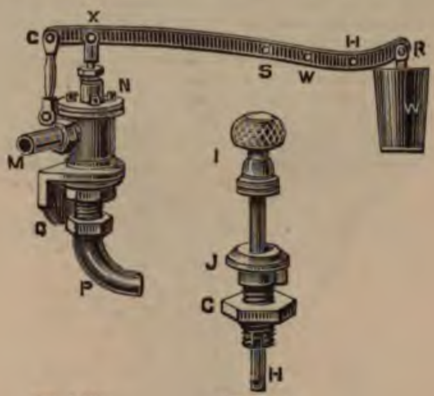


FIG. 1,537A. FIG. 1,537.

cotter-pin at G, first, you will most likely bend the spindle, and so cause the valve to jump or work irregularly when closing, and most likely cause the valve to be lop sided, and thereby leaky.

Pillar Lavatories.

Fig. 1,538 illustrates a pillar lavatory, suitable for schools, &c. The inlet supply-pipe A, may be brought up within a length of cast iron, or up the inside of the column B, with the waste-pipe W; D, is the lever to work the outlet valve; E, the overflow; F, the basin; this may be of

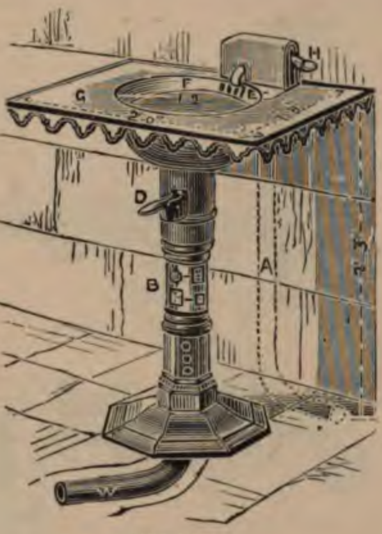


FIG. 1,538.

enamelled cast iron, as also the top G. Of course the basin and top may be had in one casting, enamelled or galvanised, or in one piece of porcelain. For school-work I cannot recommend the washer and plug being fitted to the bottom of the basin, because the plugs get lost, often thrown into a boy's ear with happy school-boy results ; and corks used in

their places, that not unfrequently are found pushed down the waste-pipe; but with the lever arrangement D, all this nuisance is obviated.

B, is the door to get at the waste-valve for repairs, &c.; A, is the overflow pipe bedded into the wall—but I of course do not recommend this for more reasons than one—but should be brought down in a casing.

FIG. 1,539.

Fig. 1,539 is a similar pillar lavatory arrangement, but fitted with hot and cold water cocks, for giving a constant stream whilst washing. I like the outlet of the two cocks

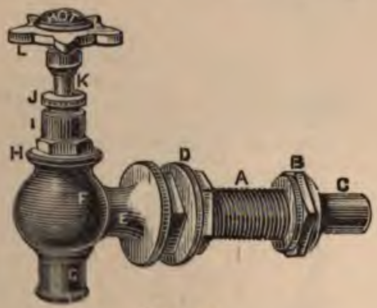


FIG. 1,540.

FIG. 1,541.

[illegible] be branched into one pipe, then the temperature of the [illegible] can be regulated; the lever D, for the outlet valve, [illegible] worked by the foot. For pillar lavatories, also see [illegible] and 1,521. One of the best kinds of inlet-cocks for this lavatory basin is illustrated at Fig. 1,540. A, is the long screw to go through a wall, or to screw to a skirting, and makes a thoroughly good fixing. Fig. 1,541 illustrates a suitable horizontal cock for such work and such places where an ordinary bib-cock cannot be used; of course the bend C, can be fitted to the cock (Fig. 1,540).

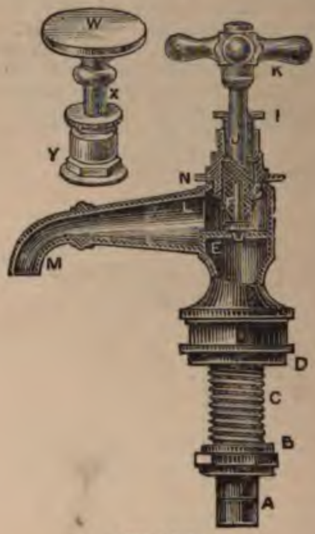


FIG. 1,542.

Fig. 1,542 illustrates a section of an upright basin valve-cock for fixing through the lavatory top; D, is the fly-nut for screwing the valve to the top or slab. This may be had with plain brass or porcelain knob as on the left.

FIG. 1,543.

12 is an elevation of a similar valve to Fig. 1,542, phragm.

Fig. 1,544 illustrates a very useful kind of lavatory basin valve-cock, embracing all the good qualities of an ordinary Chrimes' screw-down valve-cock, with the additional ground-in valve J, to shut off the water, whilst the ordinary shut-off valve E, is taken out for releathering, grinding in, &c., this additional valve being closed from the pressure

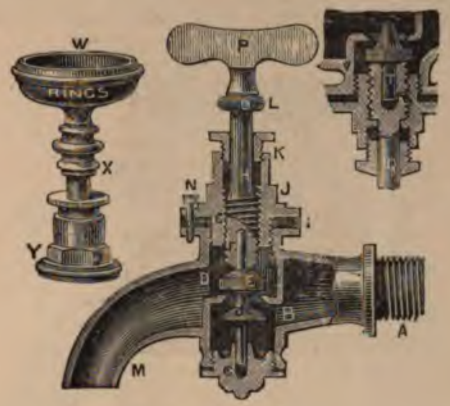


FIG. 1,544.

of water from behind, or it may be had with the extra screwed spindle with stuffing-box Q, R, T, V, fixed at the bottom of the shell at C; but in this case the bottom of the cock should be let through the slab, or otherwise kept high enough to turn. This cock may be fitted with the ring-cup W, or with any kind of fancy knob. Also see Figs. 521 and 1,022.

Fig. 1,545 illustrates an upright basin valve, of the diaphragm kind, with screws at H, for fixing the top of the valve and for fixing flush with the top of the slab, and is similar in construction to Figs. 1,542 and 1,544. The snout

FIG. 1,545.

of this cock is made flat to give a good water-way, which will take off the pressure from the rubber diaphragm, which does not, *unless the rubber be thoroughly good*, stand long together in these small valve-cocks.

Fig. 1,546 is a small diaphragm basin bib valve-cock, generally silvered; it is made in sizes from ½in. upwards, ⅜in. being generally used, and is one of the neatest designs yet introduced. For rerubbering the valve unscrew the top *b*. Fig. 1,547 is an end horizontal screw-down diaphragm basin valve-cock, also suitable for urinals, butler's

FIG. 1,546.

FIG. 1,547.

pantry sinks, &c. Fig. 1,548 is the ordinary spring-valve, also described and shown at Fig. 1,032, generally made to close with the stream; when such is the case a water cushion should be formed at the back of the valve to prevent concussion, see Figs. 533 and 1,549B (see Closet Valves).

FIG. 1,548.

FIG. 1,549.

D, Fig. 1,549 is the ordinary standard for screwing the basin-cock into, where the pipe passes through the slab; this is very handy when the basin-cock has no other fixing. F, just above Fig. 1,547, is the ordinary lengthening piece for bringing the nose of the cock forward, and over the basin when the cock is too short.

FIG. 1,549A.

Fig. 1,549A is the old-fashioned urn cock, which is a good cock for lavatory basins, having from 6ft. to 20ft pressure of water supply.

Fig. 1,549B illustrates Messrs. Emanuel's spring-action lavatory valve.

It will be seen from the section that the valves close the pressure of water, so that they are eminently s for the highest services. Further, the seating of v carefully protected by a brass casing or cap, which i perforated at the top, and through these small perfo

AA

ter is filtered, thereby preventing *débris* from coming act with the valve or seating. Above all, *to effect any it is quite unnecessary to break joints or remove the body* This latter is sometimes attended with a difficulty risky operation, and often results in a broken basin or

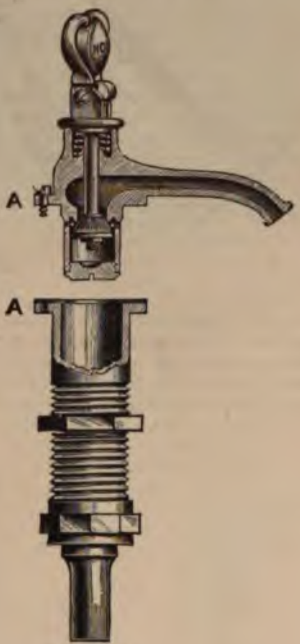


FIG. 1,549B.

The flanges at A, rest on top of the lavatory, and it necessary to loosen the screws which hold the flanges r to withdraw all the working parts. The bottom the strainer is a cylinder for the piston of the valve, events concussion.

1,549C illustrates Messrs. Emanuel's quick thread valve. The jumper or valve (the washer of which is

FIG. 1,549C.

with brass) is fitted loosely into the spindle, and into actual contact only when the valve is depressed to allow water to pass through. In closing, the spindle acts simply as a guide to the valve, which is carried to its seating by the spiral spring, and held there by the pressure of water, so that however roughly the lever may be turned no harm can result to the valve itself. This is a point of much importance, as washers are more often than not cut through simply by rough handling.

Fig. 1,550 is a waste preventing valve made by Messrs. Lambert. This firm has made this class of work a very special study; the cocks are well made and give the water

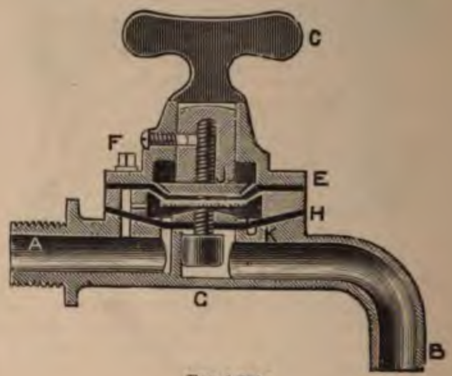


FIG. 1,550.

companies general satisfaction. The 1,027 diagram is also much used for lavatory basin work (high pressure) with or without the falling plug arrangement.

Fig. 1,551 is a very handy combination of lavatory and urinal. The waste pipe is fitted with a kind of universal joint. It was introduced by my old workmate, the late

FIG. 1,551.

William Smeaton [illegible]le a large number of these lavatories.

Lavatory Range, for Schools, Asylums, &c.

Fig. 1,552. This is nothing more than a number of lavatory basins, such as before described, fitted in a line; most of the preceding fittings may be used. This range is fitted up as follows:—First decide upon the number of basins, then have the top I, J, in which make the holes for the basins so that the rims will be flush with the slab, or if the basins are to be supported on a separate top (generally

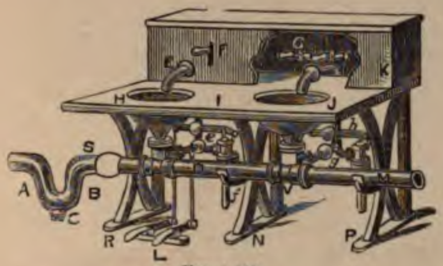


FIG. 1,552.

made of wood) then the rims must be let flush into the wooden top, and the slab bedded down with red lead upon the rims of the basins, so that the water cannot get between, for if it does these basins will be a continual nuisance. In this diagram (1,552) the top slab is shown, supported upon three standards, R, N, P; but it is not always necessary, for the slab J may be supported by letting it into the brickwork, say $4\frac{1}{2}$in., and making it good with Portland cement, or the slab may rest on a wooden bearer, say of $4\frac{1}{2}$in. arrangement, because the valves are nearly always closed. Of course, I do not say that the waste-pipe, A, S, D, N, is to be fixed of such large size or in such a manner that it will contain a lot of dirt: but, on the contrary, it must be constructed to be as self-cleansing as possible; but with every care there is sure to be filth collected in these long ranges of horizontal pipes. Lately, I have met with several fitted up with 4in. iron waste-pipe, this, for the small-waste generally fitted to washbasins, is a mistake, for such large pipes cannot be expected to be washed out. In reason, the smaller this pipe the better. Say the outlet-valve from the basin is $1\frac{1}{4}$in., then the horizontal pipe should not exceed a $1\frac{1}{2}$in. smooth leaden pipe, with a fall of at least 1ft. in 10ft.; the trap A, should be fixed as near the end basin H, as possible, with a pipe to insure fresh air from the outside of the building, but keep its end above the tops of the basins, or this pipe may some day act as an overflow pipe—that is, when the trap A, becomes blocked. I have fixed such pipes to act as warning and fresh air inlet; but it must not be done so as to become a nuisance. Of course, from the other or top end of the waste-pipe at M, a ventilating pipe must, or, at least, should be, taken to above the level of the first air inlet, so as to induce the fresh air to be siphoned through the waste-pipe. I may here state that long lengths of waste pipes often get blocked up, and all sorts of dodges have been arranged to tell when such is the case. A good plan is to fix a trap with a float to rise with the water and bring an electric bell into play, as an alarm for bad drains, &c., done twenty years ago.

Fig. 1,552A is Messrs. T. & W. Farmiloe's lavatory, with rubbed slate top grooved round to prevent dripping on floor, with quick waste-pipes and valves, with separate low basin for little children.

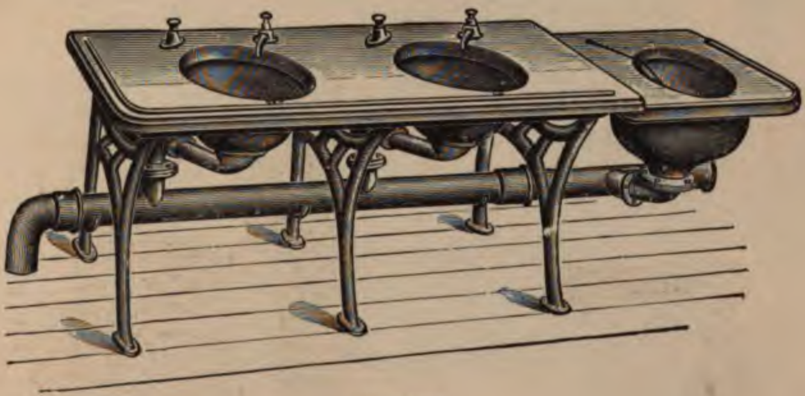


FIG. 1,552A.

quartering, let into the wall between each basin or allowed to rest upon a frame, as shown at Fig. 1,551. Having all this settled, see about the waste, M, D, S, A (Fig. 1,552). Sometimes this is done as shown in the diagram before us, that is, a pipe running along the entire length of the range, with lever-valves *g*, *h*, *e* discharging direct into the large waste-pipe, or instead of lever-valves, simple washers and plugs will answer; but when the washers and plugs are used, fix a trap below, because the plugs are nearly always left open, and the stink from the waste has every chance to come up; this is not so much the case with the lever

Lavatory and Slop Sink (Tip-up).

Fig. 1,553 illustrates a lavatory and slop sink combined, made by Messrs. Jennings. This diagram shows it used as the slop sink; and Fig. 1,554 illustrates it used as a lavatory (also see Sinks).

There are cocks on the right-hand side for drawin but they are not shown in the engraving. The ϵ shows that a basin is fitted over the soil-pipe, but trap is made with lead cone to receive the basi should it become broken no leakage can take plac.

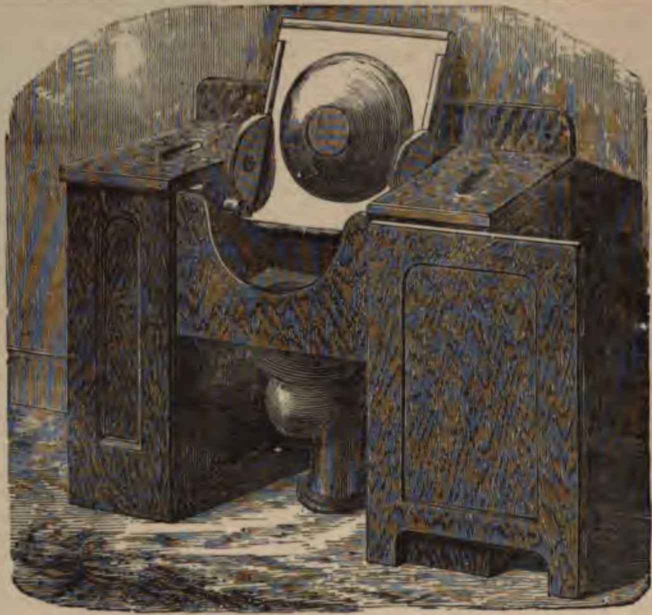


FIG. 1,553.

FIG. 1,554.

Fig. 1,555 is a shut-up very compact lavatory, and is a very useful apparatus in an office or place where other arrangements are not allowable, as it can be let flush into the brickwork.

Tip-up Lavatory Basins.

This kind of lavatory basin is shown at Fig. 1,556. G, is the container with its trunk shown bedded into the dip-pipe of the ᑌ-trap; L, is the basin. This basin swings upon two pivots at P, suitable bearings being fixed on the sides of the container; the basin has suitable stops or buffers to prevent the too sudden closing; in this case the rubber buffer is shown fixed under the spout of the cock at N, and held there by the claw. The container should be fixed below the top slab, and the hole in the slab made of sufficient size to allow the basin to swing without touching. In fixing these basins take care that the pivots are properly fastened

FIG. 1 555.

otherwise when the basin is jammed or bumped against the buffers, the basin will become loose and probably get

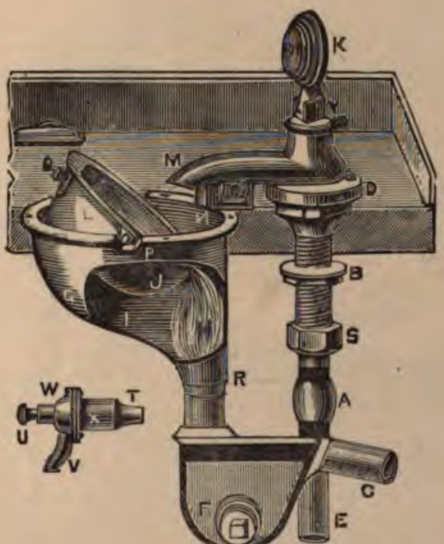


FIG. 1,55 .

broken. At T, U, V, may be seen a self-closing spring valve push cock, which is at times used with these tip-up basins, but I do not recommend them for this class of work. For another method of fixing the pivots see P, P, Fig. 1,557.

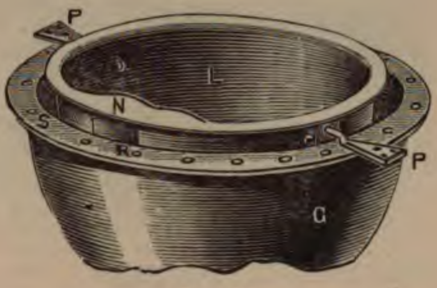


FIG. 1,557.

This is for screwing up to the top or slab, or it may be fixed to the false bottom, the latter method usually being adopted.

Fig. 1,558 illustrates a skeleton of the round container tip-up basin, as fixed over the ordinary half ɷ-trap. When such basins are fixed over these traps, take great care to well ventilate the outlet of the trap, *but not* as shown at R; for reasons, see Bad Places for Air Pipes, page 119; also see Fig. 264.

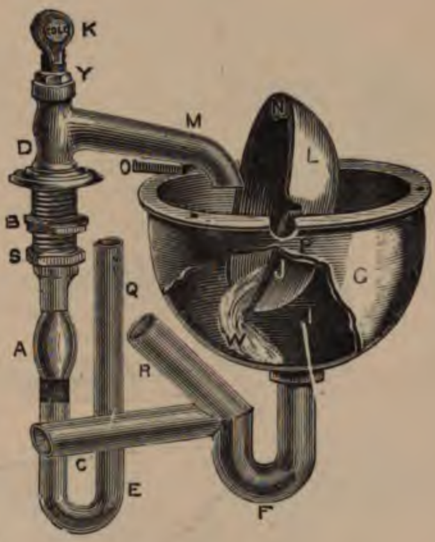


FIG. 1,558.

The air-pipe R, in Fig. 1,558, should be taken off the waste in such a manner that it cannot become choked up with the dirty water rushing through the trap, and of all badly constructed traps for such a place, it is the round pipe trap purposely shown at F, and should not be fixed. The trap for such a place must be of the ◯ class or a non-siphonic and non-waving or ebbing class, viz., a trap having a kind of flat top, as the anti-all or anti- ◯ class—important.

Fig. 1,559 illustrates the basin properly fitted up, and a little tilted to show the stop S, so that it is not always necessary to have the stops on the cocks.

FIG. 1,559.

Fig. 1,560 illustrates a two bowl circular front tip-up lavatory, fixed upon iron standards, suitable for schools, barracks, &c., made by Messrs. Jennings.

Fig. 1,561 represents one of Messrs. Jennings' tip-up lavatories of a circular form, which, at a glance, will show that a number of persons can use it in a limited space, each person standing at a different angle to his neighbour, thus giving more room than could be obtained at a straight range, as is ordinarily the case with lavatories when fixed against walls.

FIG. 1,560.

The wall space is thus made available for towels, dressing tables, hat pegs, and such like.

Plunger Cups.

This is illustrated at Fig. 1,561A, and is a most useful article for removing sediments, soap, &c., from traps or waste-pipes.

FIG. 1,561A.

FIG. 1,561.

HOT-WATER AND IRON PIPE WORK.

Hot-water Work and also Iron Pipe for Gas.

We have now come to that part of our work which is often discarded by the plumber as being beneath his notice, and by those who cannot do this class of work, as being something out of the trade; but the fact is, that our best hot-water work is generally, as it should be, left to the *qualified* plumber.

We will presume that you are thoroughly acquainted with the laws that govern fluids; but there is only one law which we shall have occasion to draw your particular attention to, that is, the law of heat when held in these fluids, for without a knowledge of such law, it would be useless to attempt hot-water work, unless it be by rule of thumb work only.

SUN'S RAYS AND STEAM.—Every one is familiar with the fact that when their hand, if of a different temperature, is applied to a hot or cold body, that the *hand* is readily made sensible of the fact, and according to the difference in the temperature so will the amount of sensation be felt. This is one way of experiencing the effects of heat. We all know that the heat of the sun's rays is felt by us all more powerfully at one time than another; but we do not all know that the heat from the rays of the sun on a hot summer's day will, on one acre of ground, produce as much steam as could be produced from a boiler consuming at least six tons of coal; and the uninformed do not know that the radiant rays of the sun traverse through space at a velocity of 190,000 miles per second, nor does he know that heat and cold are one and the same (though, perhaps, by some in a sense considered scientifically inaccurate), which according to its degree of temperature acts upon the nerves, and which sensation is experienced in strict accordance with the temperature of the applied body.

Latent Heat.

We speak of heat when this substance (if it be a substance, though probably it is a series of vibrations less rapid than those of light, and travelling through space at the same rate, and cold the absence of heat) is in temperature above that of the common air, or the applied body, and of cold when it is above that temperature. There are some bodies which may be considered as capable of absorbing heat, which absorbed heat will reside in such bodies for a very considerable time, and often in a latent state. The word 'latent heat" is spoken of, by some writers only, when the heat disappears, or is not felt, as in melting ice, boiling water, or similar operations. For instance, the heat in ice is latent, and not perceptible to our sense of feeling. For argument, suppose you place your hand into water, the temperature of which is exactly the same as that of your hand, the heat phenomena cannot be felt, therefore the heat is latent to you. For the same reason ice holds latent heat. I may remark that some use the term "latent heat" for any case in which heat is perceptible. It is usually applied only to the heat which disappears in melting ice, boiling water, or in similar operations. Ice, in air below the freezing point, cannot be said to hold latent heat, it is only when it is warmed, artificially or otherwise, that it appears to absorb 140° per pound before melting, and then this heat is called latent.

The amount of heat so disappearing, whether in liquefying any solid or vapourising any liquid, is the exact equivalent of the force required to effect the conversion. The mechanical equivalent of the heat required to raise a pound of water 1° Fahr. is 772lb. (lifted 1ft.), and that the same amount of heat is produced again by the force the liquid exerts in returning to its solid state, and the gas in becoming liquid.

The formation of steam is, a molecular change, accompanied by enormous increase in volume.

Steam.

You see that water solidifies at 32°, and will take in or absorb 140° of heat to each pound of ice before it will rise in temperature, or, if I may so speak, feels hotter; and a further 1,000° more heat must be hidden in water before the ice is converted into steam, so that we say that in steam there is 1,140° latent heat, and although we put a thermometer into this steam, it will only register 212°. This is a curious fact, and only goes to prove that which I have before written on this subject, and it is good for us that this is so, for if all the water were suddenly to turn into steam, an explosion would take place every time we boiled a drop of water.

BOILER EXPLOSIONS.—I may add that you may keep boiling away at water, and so drive away all the air held in solution, and when such is done you may raise the temperature to at least 360°; you are then liable (if the air be absent) at any moment to have an explosion. For my own part I am quite convinced that many of our terrible boiler explosions which have never been accounted for, have been caused by the continual boiling of the same water, which is often the case for days and nights together, and must drive off the air held in solution before spoken of.

To prove this, take a piece of Wenham ice, and place it in a large test tube, then cover it with turps (turpentine). Carefully melt it, and without admitting the air make it boil. The heat required will be considerably more than 212°, but as soon as a certain degree of heat is touched much beyond 212°, steam is generated, and the whole of the water will jump up out of the tube as though gunpowder were under it!

I have said that the temperature of issuing steam is never more than 212°, but it must not be lost sight of, that water may be heated to a very high temperature, according to the strength of the vessel wherein it is held. And when this is done take particular notice that you leave sufficient room in the vessel for the expansion of the water, which will expand when heated from 39·40° (the greatest point of condensation) to 212°, one twenty-third part of its bulk, and if enclosed within a close vessel, will exert a power of 14,121 lbs. on the square inch. It also should be known that water in our common atmosphere boils at 212°, but double the pressure of the atmosphere on the surface of the water, and though this may at first sight appear paradoxical, it will not boil before it has attained 250·52°, and if your vessel be constructed so as to resist, say, 25 atmospheres of pressure then your water will not boil until it has attained the heat of 439·34°, providing there be not the usual amount of air present in the water.

Water, and Steam Product.

I may here state that one cubic inch of water will make 1,696 cubic inches of steam, compressed to 15lb. to the square inch. The following may assist you in your reasoning respecting the quantity of this latent heat. You may say that snow is the very essence of cold, but in comparison to the following will feel quite warm. Take two bowls of snow, and put into one bowl half as much common salt. Place your hand into this mixture, and you will be very pleased to withdraw it, if only to place it in the bowl of pure snow, which will then seem to be warm, and of course the heat not latent. I may add that when mercury is frozen, the mere act of picking it up with the naked fingers, will blister them, just as if it were a piece of hot iron. These are simple experiments whereby you may be better able to judge what constitute the different forms or states of heat—latent, radiant, or otherwise.

Susceptibility of Different Bodies to Heat.

SOLIDS AND HEAT.—We now know something of latent heat: we may, therefore, turn our attention to the susceptibility of bodies to heat. Water is said to have thirty times more capacity for heat than mercury, and there are three methods by which heat is diffused, viz., by conduction, convention, and radiation, and the rapidity in which heat travels varies in different substances, which is proved by placing a silver spoon with a wooden one of the same size into boiling water, the handle of the silver will become too hot to be held before the wooden one is sensibly warmed, hence the reason for using wood on the handles of spanners. The rate of heat-conducting materials is as follows: 1,000 gold, 973 silver, 898 copper, [illegible] platinum, 374 iron, 303 tin, 179 lead, 23 marble, [illegible] porcelain, 11 clay.

LIQUIDS AND HEAT (RATES OF).—In liquids this change of temperature is by displacement of particles, which will give rise to your attention to heating by hot water. If the heat is applied to a boiler of water, the particles near the heat become expanded, and thus superficially lighter and raised, making room for the colder particles, [illegible] in Fig. 1,573. It is here, evidently, [illegible] from that of conduction, the heat not [illegible] from particle to particle without actual [illegible] and here is the system of convention of [illegible] apply the heat to the surface of the water [illegible] proof that water is a bad conductor, [illegible] whilst the bottom will remain [illegible] speaking.

[illegible] HEAT. Gaseous bodies, of course, [illegible] of their particles, are rapid con[illegible] the slowest conductors of [illegible] appear curious, but is well [illegible] dry hand into an oven [illegible] and then place your hand [illegible] which I should not [illegible] the hand in the oven, wetted.

[illegible] WITH WATER AND [illegible] a jar of warm water [illegible] cold winter's day). Now [illegible] bottom of the jar, and one [illegible] the top thermometer [illegible] are reduced to 40°, [illegible] will register the lowest. [illegible] much as the [illegible] the colder water [illegible] as say, Iceland [illegible]

Boilers, Kitchen.

Now, being fairly well acquainted with the qualities of heat, it is time to see and know something respecting the boiler, of which there are various kinds, but those with which I shall deal with first will be kitchen boilers.

Fig. 1,562 at A, illustrates a welded shoe or boot boiler. Fig. 1,563 is the same class of boiler, but having an arched flue thereunder, suitable for places where the flat bottom boiler would be too low to get a flue below the boiler. I, Fig. 1,568 is an ordinary wrought iron square boiler, having a flue thereunder. J, and K, Fig. 1,568, are square twin boilers. E, Fig. 1,565, is a register stove bath boiler. Fig. 1,571 is a square, slanted front boiler, having a flue hole therethrough. L boiler is shown at Fig. 1,567, G, being a close or high pressure boiler, and H and L, low pressure boilers, generally used for common ranges, whilst Fig. 1,570 illustrates an L boiler with a flue at M. L, Fig. 1,569, illustrates a double-arm or double-shoe boiler. F, Fig. 1,565, is a square open top boiler. D, Fig. 1,566, is the same boiler with rounded nose. Fig. 1,564, is a toe boiler. I shall say more about these boilers as we proceed.

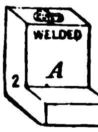


FIG. 1,562.

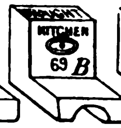


FIG. 1,563.

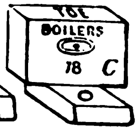


FIG. 1,564.

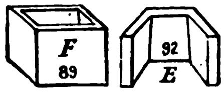


FIG. 1,565.

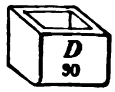


FIG. 1,566.

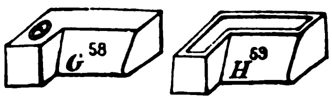


FIG. 1,567.

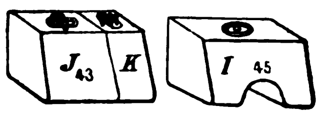


FIG. 1,568.

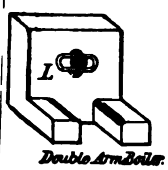


FIG. 1,569.

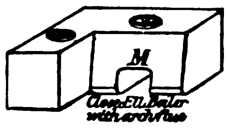


FIG. 1,570

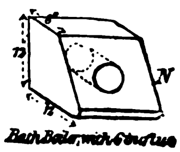


FIG. 1,571.

Being well acquainted with the qualities of heat, the first thing now is to know exactly what is wanted to be done. It may be simply an apparatus for heating, or it may be for baths, &c., and for simplicity's sake I will first draw your attention to a job in hand. Let us assume that it is for baths, say from [illegible] kitchen boiler, and, as illustrated at Fig. [illegible] boiler. (Also shown at

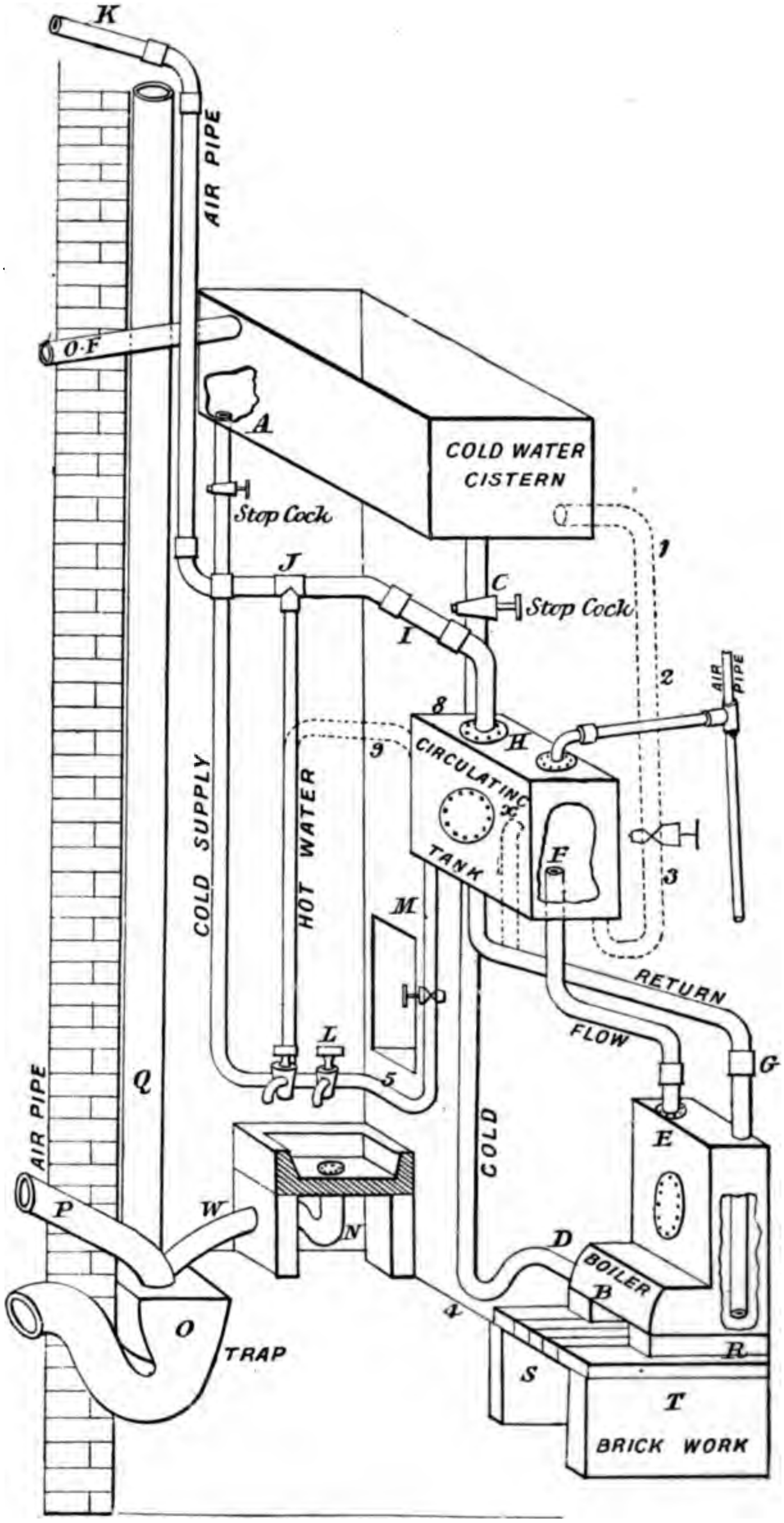

K
AIR PIPE
O·F
A
Stop Cock
COLD WATER
CISTERN
1
J
C
Stop Cock
I
2
AIR PIPE
8
9
H
CIRCULATING
TANK
x
F
3
COLD SUPPLY
HOT WATER
M
L
5
RETURN
FLOW
G
AIR PIPE
Q
E
COLD
P
W
N
D
BOILER
B
4
O
TRAP
R
S
T
BRICK WORK

FIG. 1,572.

Fig. 1,562, but here the man-hole is on top.) R, G, Fig. 1,572, is the return pipe connected to the bottom of the tank, and also to the bottom of the boiler, as shown at R, and so called because the cold water returns from the hot water circulating tank by way of this pipe to the *bottom* of the boiler. F, is the flowpipe, which must never dip—that is, it should have a gradual rise from the boiler to the circulating tank, without the least part of it descending or falling the reverse way throughout its whole length. This is of great importance, because if the flowpipe dips, it will hinder and check the flow of water, simply because the hot water always tends to ascend and never to descend. This flowpipe should come off the top part of the boiler, and without the least dipping into the boiler. It should also be taken up into the hot water tank to stand about 2in. or 3in. higher than the return pipe, as shown at F. Sometimes when the hot water tank is a deep one, and you do not wish your hot water to pass through the cold into the tank, you may take the flowpipe in the side of the circulating tank, as shown by the dotted lines as at X, or even into the top of the tank; by doing this the hot water accumulates in the top of the tank, and may be drawn off with an advantage, though this is not generally done. Of course the ends of the flow and return pipes entering the tank may enter at the side or otherwise, or even the hot water or flowpipe, as before said, may enter at the top of the tank, as at H. The return pipe may go through the side of the boiler near the bottom, or through the top, and with a short length taken down into the boiler, as shown. In some cases, the flowpipe cannot be taken off the top of the boiler; then take it off the side as near as possible to the top, and in such a manner that the boiler can remain quite full of water at all times, and without the slightest particle of steam chest room.

The Cold Water Cistern.

This is shown and the name printed thereon; 1, 2, 3, is the cold supply pipe, which should have a stop-cock to shut off the water, as at 3. The pipe may be trapped, as shown by the dotted lines near 3, and taken into the hot water tank, or to the return pipe, or it may be taken a few inches below the bottom of the boiler, so as to trap it, as at 4 (*which will prevent the hot water descending this pipe*), and then taken into the bottom or side of the boiler, as shown at D. C, is the stop-cock. The cold water supply to the hot water tank may be as shown at 5, M, but when this latter method is adopted, you will be apt to draw hot water at the cold water cock, L, especially if the cold water supply pipe between the cistern and draw-off be of a greater length than that between the draw-off cock and the hot water tank, or the pipe between the cold water cistern be small in bore, or having many sharp turns, or having to pass through a Rotherham cock or other screw-down stop-cock. Now, to get over this difficulty, a check or spindle valve may be screwed on to the end of the pipe, M, (of course inside the cistern), or a Rotherham stop-cock may be fixed at 5; but the stop-cock must be fixed so that the valve will, by its gravity, fall fairly upon its seating, and in such a manner that it will form a back valve, so that the water cannot flow back. Or, in order to do away with these valves (which, to say the least, are objectionable, and not to be used, only in isolated jobs, though they answer their purpose; but, of course, this work is not what I should consider perfect; it should be remembered that circumstances alter cases, and then the above "wrinkles" will be found exceedingly useful), a much better plan will be to take the cold water supply pipe, M, to the top of the hot water tank, and branch it into the top corner of the tank at 8. Then, in this case, it will be impossible for the hot water to be drawn off by the inlet pipe. Many will say that this system is contrary to that generally in use. So it is. But let this be as it may, the system works exceedingly well, and often may be fitted when needs drive. I, J, is the draw-off pipe from the hot water tank, which, being continued forward to AIR PIPE and to K, carries off all steam, and allows the air to flow from the hot water tank when it is being filled with water. It should be *properly protected from frost*. I do not like this style of drawing off the water from the tank, but prefer to fix the draw-off pipe about 3in. to 6in. down the tank, as shown at the dotted lines 9, as this prevents the air being drawn down with the water when in use.

HOT WATER is the pipe, branched off the before-mentioned air pipe, which form I object to, to supply the sink.

In the preceding I have drawn your attention to the hot-water fitting, such as is done by plumbers, &c., generally, and will assume that you are, in practice, tolerably well acquainted with; but, if I were to ask you the reason why such apparatus works, the chances are that I should receive an unsatisfactory answer; and to enable you to thoroughly understand this class of work, so as to be able to fit up works of every class, it will be imperative that you should be thoroughly grounded in the principles which govern this important branch of your work, so that you may not be, as many of our leading foremen of plumbers are, simply obliged to come and seek information which, I say, every apprentice boy should be able to give before he is out of his time. I may also state that I have, by the plumbing craft, been asked to thoroughly explain the theory of hot water work, together with the practical part, not only suitable for the apprentice boy, but also for the foreman and master.

The Theory and Experiments of the Circulation of Hot Water through Pipes, &c.

It will be seen that heat is diffused through water in a very different manner to what it is through solid substances. When the heat is applied to the bottom of a boiler or other vessel containing water, the first effect is to expand the layer of water nearest the fire. The fire, by reason of its heat, makes this layer of water specifically lighter than the colder water which may be by the sides, and especially that above; and this layer being lighter than the cold above, it allows the colder water to descend, when the hot water naturally rises, or floats upon the molecules of the colder or denser water which surrounds the hot; then the cold water from above, by reason of the extra density, immediately sinks to the bottom of the boiler, when it again becomes heated and again lighter in its turn. These succeeding fresh layers of heated water will continually carry the heat from the bottom of the boiler to the highest point of the circulating tank, which heat, if the pipes and tanks be not too large, is finally and gradually diffused through the whole of the water within such pipes and tanks.

For an illustration of this beautiful system I will ask you take an ordinary tin can, or, better, an oil flask or other bottle, and nearly fill it with clean water, into which put some bran, or other light substance, which will not altogether float; then put it over an ordinary gas burner, lamp, candle, or other fire, so that you may be able to watch the action of the water. You will see that from the first moment the bran, &c., will be in motion, rising upwards just above the heated part, and, as shown by the arrows, B, C. D. Fig. 1.573, and downwards at the colder sides, E, F [illegible] candle on the other side, and the action [illegible] ace the candle in the centre of the [illegible] otion will be in the centre.

Having got so far, next try this experiment with a bent glass siphon, as at Q, P, W, S, Fig. 1,574, which may be made from an ordinary glass tube, procurable at most chemists, who will also bend it for you, or you may do it for yourself, by making it red hot over a fire; or, if you cannot get this, procure a pail or a deep saucepan, and bend a piece of compo. tube to the shape; let the bottom leg go to the bottom of the saucepan, but cut on the splay, so as not to stop the waterway, let the short leg just dip

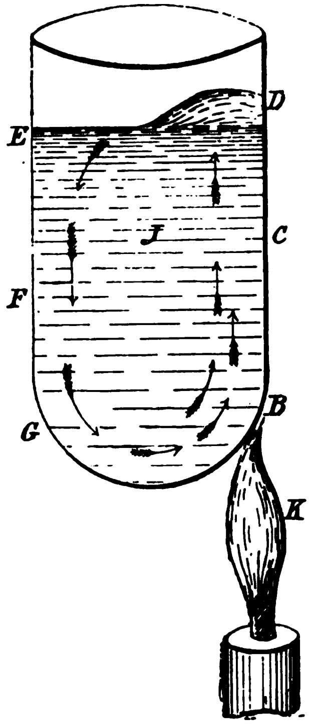


FIG. 1,573.

an inch or two into the water. Now fill the siphon *quite full* of water, and put the two legs into this water, as shown. Set the pail over a fire, and you will soon find that the siphon will be the hottest, showing that, by reason of the extra length of water in the long leg, the action of the water is more rapid through the siphon than that within the pail, and well establishing the fact that the hot water will travel through any length of pipes as at FLOW and RETURN, Fig. 1,572.

Expansion and Contraction of Water. Frost Bursts (Cause of).

It would appear (from the preceding facts) plain that the colder the water the heavier it would be, while the lighter and warmer particles will rise to the surface; but even in this there is a limit, which can only go down to 39·2°, when the maximum density of water is obtained. The consequence is, that water of this degree of heat must sink through any water below, whether it be of a higher or lower temperature. Having found the point or degree of heat where the water is of its greatest density—viz., 39·2°, it will be self-evident that by adding degrees of heat to water, that this warmer water must float; whilst, on the other hand, if you lessen the degrees of heat, this colder water will also float; and if the water be cooled down from 40° to 32°, it will expand in bulk (being about one part in ten thousand at 32°), and will occupy the same space that it did in sinking from 48° to 40°. When the water is at 32° it appears to remain at this degree, and will gradually solidify or crystallize into ice; but in doing

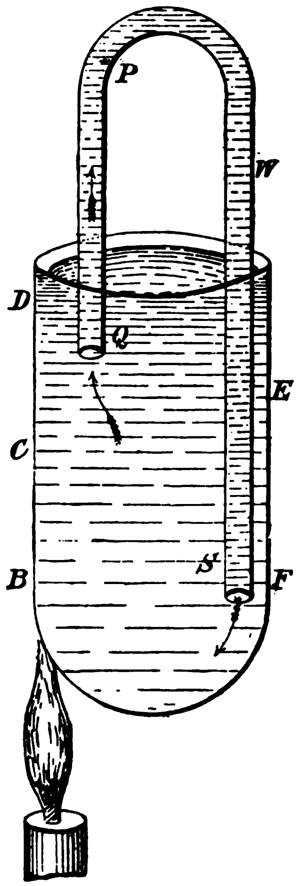


FIG. 1,574.

so, the latent heat (143 units) is extracted, and the water expanded 9 per cent. (a slight expansion of the water goes on in strict accordance to each degree of cold below 32°); and should water be in any way confined within a pipe, &c., during this expansion by frost, &c., there is no alternative but for the vessel to burst, which accounts for pipes bursting during times of frost.

Circulation of Hot Water.

From the above, it is plain that the circulation of hot water is brought about owing to the difference in the weight of the water at different points, caused simply by the expansion and contraction of the water itself; th fore, if the source of heat be permanent, the particles

rapidly brought into action, and the particles in a vertical tube soon become heated, and by their expansion must exert effective pressure on all parts of the pipes, branches included. Now this, together with the levity of the water in the boiler, establishes a current, when the cold water from the coils, branches, &c., commences to flow in the direction of the boiler, and thus supplying the heavy or colder water continually, which, of course, takes the place of the lighter particles, known as hot water. To find the force with which the colder water runs towards the boiler, you must know the specific gravities of the water in the flow and return pipes, the flow being the ascending, and the return the descending; the difference between them will be the motive power, or the effective pressure. You can arrive at this point by ascertaining the temperature of the water in the return pipe and boiler, or flow pipe. If the difference in heat is only a few degrees, of course the difference in the speed of circulation of the water will be accordingly; say it is only four or five degrees, which is very small, but quite sufficient in a we l-arranged system to maintain constant circulation. Let us assume that we have 8° of heat in our boiler, B, see Fig. 1,575, the return

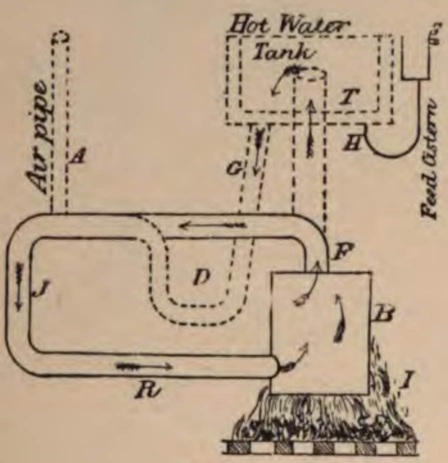


FIG. 1,575.

pipe is standing at 180° and the flow to be 188°. Let the flow pipe at F, be, say, 18ft. above the bottom of the return, R; the difference in weight will be about one-third of an ounce on the square inch, and this will be the amount of motive power obtained for the circulation, no matter what may be the length of pipes attached to the apparatus; and should there be, say, 50 yards of 4in. pipe, which will contain 50 gallons of water, with a 15-gallon boiler, you will then have 95 gallons or 950lbs. weight, kept in continual motion by the 8° of heat, or one-third of an ounce pressure.

Of course the size of pipes will make a wide difference in the motive power, which increases with the size of the pipes; thus, in a 4in. pipe you will get four times as much as in a 2in., and so on, but, as the resistance increases equally with the power, the actual working effect is precisely the same in all sized pipes.

Again the motive power can be increased by allowing ... cool down before it gets back to the boiler, ...sing the height of the flow and return pipes, ... the difference of the temperature between ...a, or, of course, an extra power can be ...bling the difference of the temperature between the return and flow pipes, when the same increase of power is obtained by doubling the vertical heights; or by trebling the vertical height of the flow and return pipes the same effect is produced as by trebling the difference in the temperature of the water.

A difference in the motive power is also made by diminishing the diameter of the pipe in such a manner that a longer amount of surface will be exposed, and in proportion to the amount of water within this, of course, allows more cooling surface, and consequently the return pipes can give off more heat in a given time, thus making the return water denser, and consequently quicker in action. Of course, when you do this you have more friction, which will be readily understood from the following:—

It is certain that the sides of the pipes greatly retard the flow of water, therefore a considerable deduction must be made, in some cases to the enormous extent of 80 per cent. (See Friction of Water through Pipes and Bends.) In small pipes there is a greater amount of friction than in larger ones, owing to the relative amount of surfaces; besides, these small pipes cool quicker than larger ones, and thus the velocity is increased, as also is the friction, so that supposing we have a 4in. pipe, the amount of friction is, say, 1, in a 2in. there is twice as much, and in a 1in. four times as much as in a 4in., and you should also know that by increasing the velocity, so in proportion will be the friction nearly as the square of the velocity. It should also be known that in all hot-water apparatus the speed of circulation varies according to circumstances, therefore it is difficult to calculate; one thing is certain, that the velocity in hot-water pipes is quickest in their centres.

Velocity of Water through Hot Water Pipes.

The following is an easy method for estimating the velocity of hot water through pipes. Take an inverted siphon, Fig. 1,576, and place one inch of mercury in one leg, as at X, G, and water in the other, as at A, B; it will be found that the one inch of mercury, X, G, will balance

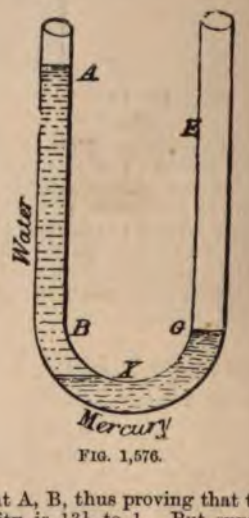


FIG. 1,576.

13½in. of water at A, B, thus proving that the difference of the specific gravity is 13½ to 1. But suppose you use oil instead of mercury, then the water, ... will ... the heaviest, and a column of 18in ... column of 20in. of oil; now sup... stop-cock at X, and then put oil ...

and water in the other, so that each fluid will stand at one level. Now suddenly open the stop-cock, and you will find the oil to be forced upwards with equal velocity to that of a solid body falling by gravity through a space equal to the additional height which the lighter body would occupy in the siphon. Seeing that the relative weights of oil and water are as 9 is to 10, the oil must by the water be forced upwards with a velocity equal to that which a falling body would acquire in falling through one inch of space, which is equal to a velocity of 138ft. per minute, therefore you must estimate the speed of water in a hot-water pipe by the above rule.

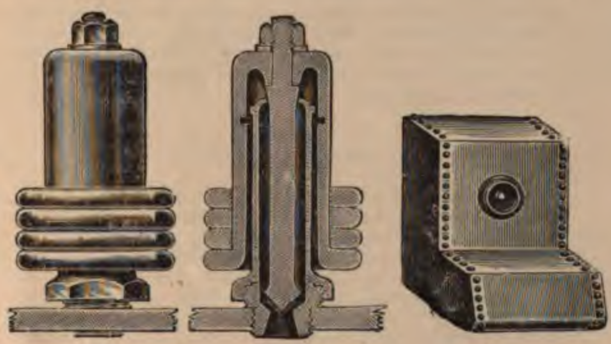
Now, suppose your flow and return pipe columns to be 10ft. high, and your flow pipe to be 8° hotter than the return, the hottest column of water will stand at ·381 of an inch higher than the colder, or there will be rather more than one-third of an inch the difference in the height of the two standing columns, which will give a velocity of 79·2ft. per minute; or if the height be only 5ft., and the temperature as above, then the velocity will be 55·2ft. per minute, showing that the height of the two water columns, viz., 5ft. and 10ft., make a wide difference in the velocity of the flowing water. We will suppose the above temperature to be now doubled, viz., 16°, and the height of flow and return to be 5ft. Now, that being so, the velocity will be 79·2ft. per minute, and so on proportionately.

Now that you thoroughly understand the principle of the circulation of the particles of water through pipes, &c., all the other work will be simple. You will find that the fittings described and illustrated will, after what I shall write, be A, B, C, to you, and more especially as I intend to explain them in the simplest manner possible.

Safety Valves.

Fig. 1,577 illustrates a safety valve and boiler.

A, is an elevation, and B, a section of Hartley & Sugden's safety valves for kitchen boilers, generally fixed on the top of the boiler, or as you please. C, is a riveted wrought-iron shoe boiler, made by the same firm. These are the first two things to look after.



A B C

FIG. 1,577.

The first thing to be known is the amount of hot water required for the work. Suppose that it is required to fit up a gentleman's house of, say, three sinks—viz., scullery, butler's pantry, and one housemaid's sink—one bath, and ...vatories, a... 339 and 340. Here your circula- ...50 gallons. The boiler should ... is a boot boiler, as at C, ...e to side, 8in. back, and

boot, say, 4in. from the sole to the instep at 2. The width of the boot is generally the same as that of the boiler. Let this boiler be about 15in. to 18in. deep. But it may happen that you have a boiler with the range, so that you will not get the chance of choice, but when you have the choice see that you select one large enough, and should you not get the chance of selection, and have one which you think will not do the work, make your ideas known in the proper quarter, so that the onus of blame will not rest with you through not speaking in time. I say again that you should make it your duty to see that it is large enough, and properly set, and in such a manner that you can get a good fire flue under it, as shown at FLUE, Fig. 340, and well up the back, as shown at K, Fig. 1,578, at the top of which must be fixed a damper, to prevent the water boiling away when there is too much fire for the amount of work to be done. In this engraving, Fig. 1,578, may be seen a method of fixing the boiler and hot water tank and pipes; and in such a manner that the circulating tank cannot be emptied—a very necessary thing when the water is apt to become short, and is very useful in times of frost; for, if the circulating tank be of a size proportionate to the boiler, the arrangement may be worked for days after the supply has been cut off. In this arrangement it will be quite as

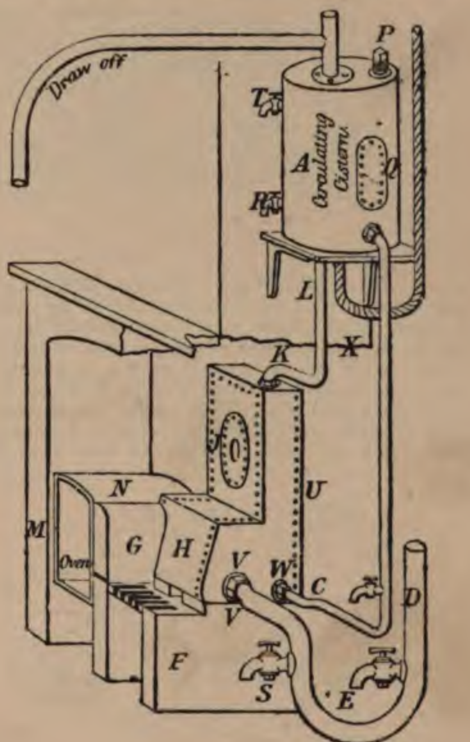


FIG. 1,578.

well to fix gauge-cocks, as at T, R, so that the presence of the water within the tank may be known. If the cock R is fixed within, say, 1in. of the bottom, and the water will not run, it will at once be known that there is not sufficient water, and the fire must be put out, or the tank filled through a plughole at P, or otherwise. T, is the gauge-cock, to tell when the circulating tank is full. Fig. 1,578 also illustrates the connections and pipes between the round

circulating tank A, and the boiler H. L, K, is the flow-pipe, which takes the hot water from the top of boiler to the circulating cistern or tank A. C, is the return pipe which takes the colder water from the circulating tank to the boiler; S, E or D, the emptying cock, the plug of which should be square-headed for a spanner; the air pipe and draw off are in one (see DRAW OFF). D, E, the cold water supply or feed pipe, trapped at E for preventing the hot water from flowing back. S, may be the *square-headed key* emptying cock instead of D. *This emptying cock should be out of the control of the servants, &c.*, or, instead of the cold water supply coming into the bottom of the boiler, as at V, the cold supply may be taken into the bottom of the circulating tank, as shown at Q, X, L; but this is not so good a principle as that shown at V, because in the latter case – viz., with the pipe V, E, D—the whole of the hot water is always driven out of the boiler before the cold can enter the circulating tank. J, is the manhole for clearing out boiler. There is also a manhole in the circulating tank, as shown at Q. When open fireplaces are used, as at Fig. 1,579, sometimes an ordinary square boiler, as at I,

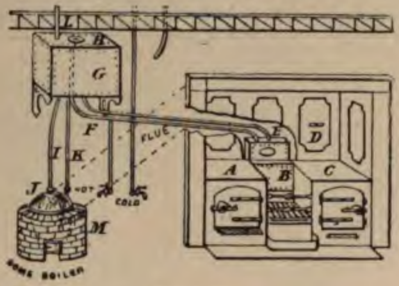


FIG. 1,579.

and J, Fig. 1,568, is fixed sometimes with and sometimes without a boot; but, when the latter is the case, be sure to have plenty of *flue room* and *heating surface*, for such boilers, as a rule, unless properly set, are very sluggish in action, and it will be better if possible to use an L boiler, such as is illustrated at G or M, Figs. 1,567 and 1,570. If there is not much chance of getting a flue below the boiler, then this may be got over by using the boiler I, or B, Figs. 1,563 and 1,568, with arched flue, which partially

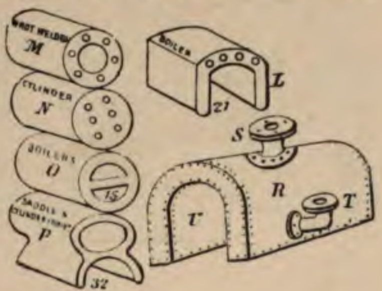


FIG. 1,580.

forms a flue in itself, and if the fireplace is expressly for the bath and hot water work, such as you may have to fix in a bath room, then the register stove E, Fig. 1,565, may be used. With this boiler there is plenty of heating surface; but remember you should always try to get a draught under the bottom and up all sides and back to ensure a quick action. I have fitted up such boilers having a flue space, as at I, Fig. 1,568. You may use square boilers, having a flue hole through, as at N, Fig. 1,571, or such boilers as are shown at L, M, O, P, and R, Fig. 1,580, and also the copper domed boiler, shown at Fig. 1,581, or the saddle boiler, Fig. 1,582, for quick heating and special work, all of which must be set to ensure the best draught, and to expose the sides and bottom parts to the action of the fire, and in such a manner that the fire will travel

FIG. 1,581.

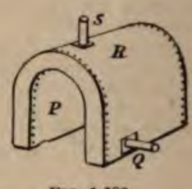


FIG. 1,582.

backwards and forwards, and play upon the boiler in the best possible manner, and fixed so that the flues may be readily *cleaned out*, and not become choked up with soot, &c. This is generally looked out for by the bricklayer; but every plumber should be in a position to see that it is done, and to instruct him how to set the boiler so as to get the best work with the least amount of coals.

I have on many occasions set my boilers to heat *too* quickly. When such is the case the *boiling* hot water when entering the cold water will bump and rattle away like so many guns. This is easily got over by reducing the fire-space with fire bricks, lumps, &c., &c. It is a good fault when properly understood. In the year 1872 I personally fixed one for Mr. Carey, the well-known cheese merchant, at his residence at Shepton Mallet, which heated 108 gallons of water in 15 minutes, with a boiler 18in. long by 15in. by 6in. deep. The circulating pipes were only about 8ft. long, which, when the fire was first lighted, made such a noise, although there was not the least danger, that the servants all ran away out of the house, and it would also alarm many other people. I, in this case, took the flow-pipe to the top of the hot water tank, which allowed the whole thing to work quietly, because then the hot water mixed with the hot water in the tank, and not with the cold at the bottom. Such may be made to work quietly by reducing the water passage through the *return* pipe; the same may be checked by the use of elbows, long lengths of pipes, such as a coil, &c.

Dome-shaped Boilers.

If you refer back to Fig. 1,579, you may notice a little dome-shaped copper boiler fixed in brickwork, as at DOME BOILER. This is a much better arrangement than having a gas bath. The boiler here fixed is shown at Fig. 1,581, which will, after what I have said on boilers, explain itself; but sometimes a small copper saddle boiler, such as is shown at Fig. 1,582, is used. When the latter is employed, fix it so that the whole will be encased with brickwork.

Water Hammer and Bath Boilers.

Before proceeding further, I wish to say a few brief additional words respecting the rumbling or crackling noise which is occasioned by the sudden introduction of steam into water, and known as the "water hammer"; also see Injectors and Heating Water, Water Hammer, &c. Now, when steam is passing through a pipe, and suddenly discharges itself into cold water, the first contact of the two fluids is accompanied by a sudden condensation, and

the rapidity of the impingement causes a sharp blow to be struck, usually at the point of entrance; while, if steam be continued, a succession of such blows occurs, and according to the size and inclination of the pipe, so will be the loudness; and in accordance with the pressure of steam so will be the rapidity of each blow struck. This phenomenon may again be reasoned out as follows:—The pipe may come in contact with the surface of the cold water standing in the pipe, when condensation immediately occurs. This condensation suddenly produces a vacuum, and the water surrounding this vacuum is instantly injected into the vacuous space, and the rapidity of the water striking the surrounding surfaces strikes a blow like that of a solid body. The enormous velocity with which these two fluids meet at the intermediate spot being instantly checked, a collision takes place, which, at times, is sufficient to split a welded iron pipe tested to 400lb. to the square inch. See Experiments with Water Hammer.

Boiler Capacity for Heating.

A saddle boiler, 18in. long, 10in. wide, and 11in. deep, if properly set, will heat 200ft. of 4in. piping; but you must not lose sight of the fact that unless it is properly set you may not be able to heat 20ft. The following is the method of fixing (see Fig. 1,583):—B, are the fire bars,

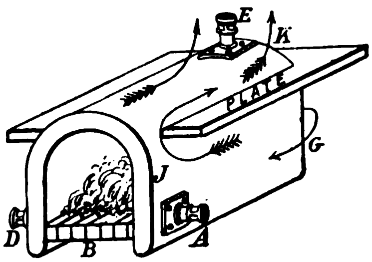


FIG. 1,583.

which should be fixed at the bottom of the boiler, but sometimes they are fixed higher. The boiler should be set in such a manner that the heat will pass through the arch and out at G, passing along the bottom and under the PLATE, up the flue space, J, and over the top part of the

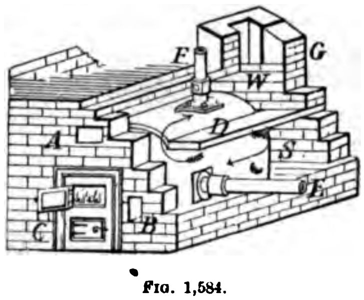


FIG. 1,584.

A — —ere should also be provided proper ". as at A, B, C, Fig. 1,584, ler when set in brickwork. found to work satisfac- long, 10in. wide, and 11in. deep, should heat very easily 200ft. of 4in. piping, or you may with good fuel and other arrangements heat from 250ft. to 275ft. See table, which I have calculated upon the minimum scale.

Green House Boiler Table.

Size of Boiler.			Length of 4in. Piping heated.
Length.	Inside width.	Inside Depth.	
in.	in.	in.	ft.
18	10	11	200
24	10	11	250
24	12	12	300
24	12	12	325
27	14	14	375
30	14	14	425
36	14	14	500
42	18	18	800
48	18	18	900
48	21	21	1,000
54	24	18	1,200
54	24	21	1,300
60	24	21	1,500

Some boilers are made with flueways through the top part of the boiler, as at H, I, Fig. 1,585, and at E, Fig. 1,586,

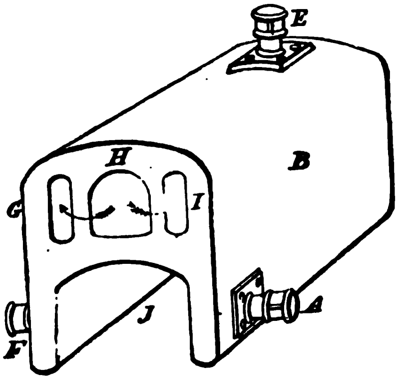


FIG. 1,585.

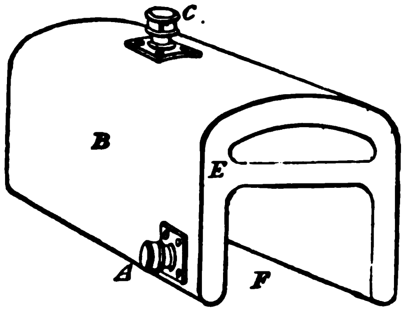


FIG. 1,586.

whilst others are made with waterway mid-feathers, as at J, K, Fig. 1,587, also as shown in the section Fig. 1,588, in

place of the usual mid-feathers shown at PLATE, Fig. 1,583. Of course, these waterway mid-feathers give a greater amount of *under* heating surface, and I may say that there are scores of different methods whereby this end can be attained. For instance, tubes can be fixed across the internal part or archway of the boiler, as shown at B, F, Fig. 1,589; and take particular notice that the principle always to be kept in view is to expose the largest amount of *under* heating surface to the fire in the smallest

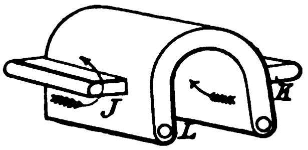


FIG. 1 587.

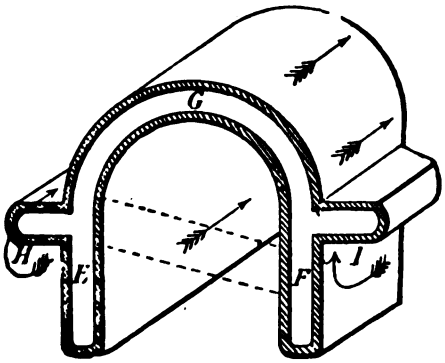


FIG. 1,588.

possible space, so as to absorb all the heat which is given off from the fuel; and secondly, to have your boiler formed in such a manner as to allow free circulation of the water throughout its entire extent. The latter is of great importance, because if there are any parts of the boiler which do not allow the water to freely circulate, that part of the heating surface may be considered as next to useless, for it is this free circulation which we have to depend upon for the useful effect of the boiler itself; in point of fact, were

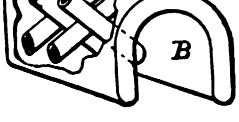


FIG. 1,589.

it not for this free circulation the pipes could not possibly become heated. Now with respect to the size of the boiler, 4 square feet of surface in an ordinary boiler under the direct action of a middling strong fire will evaporate a [cu]bic foot of water from the temperature of 52°, and will [give] sufficient heat to 225ft. of 4in. pipe to keep a [green]house at a temperature of 150°; but, of course, much depends upon what draught you get, and [c]lass of fuel used. The following is an easy [way of] calculating the size of boiler necessary for greenhouse heating purposes:—One foot superficial of boiler exposed to the fire, with well regulated flue space, will heat 50ft. superficial feet of piping; but as a matter of course, the time of year very much interferes with the above calculations. I have calculated the work necessary for the winter season, and for ordinary greenhouses, and to give sufficient margin to allow the gardener to regulate his heat according to his fuel. The furnace bars will make a great difference in the working of a hot water apparatus, for if they are too wide, the fuel is apt to tear away: for instance, if it is required to obtain the greatest amount of heat in the shortest time, the bars should be wide enough to allow a good draught to the under side of the fire. Again, the area of the furnace bars will make a great difference in the working of the boiler; ordinarily speaking, say, 12in. by 15in. of furnace bars will very easily heat 250ft. super of pipe. Many make a great mistake in making their furnace bars the whole length of the boiler.

Dips in Hot Water Pipes.

For this refer to F, G, Fig. 1,590. Here is a bend to look down, and another bend to carry along horizontal 5ft. or 6ft., and then rise again by the same means, so as to allow of the opening of a door. Here let me draw your attention to the engraving, Fig. 1,590, with the following brief description:—Let Q, H, be the flowpipe or rising main off the top of boiler, and I, F, the horizontal pipe, rising gradually from I, to F. Here everything is all right; but from F, to G (the place for your doorway), is a trap, and as the hot water is lighter than the cold (situated between F, G, B, and E), it cannot, of its own accord, descend; which will be understood as follows:—Suppose

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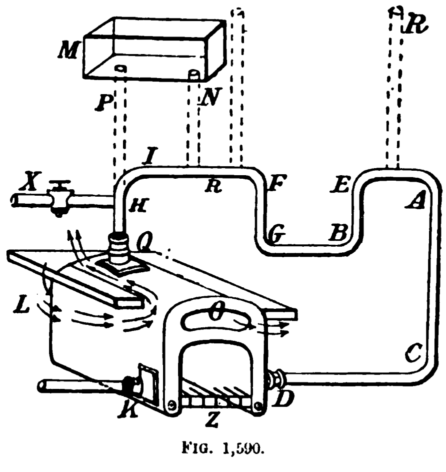


FIG. 1,590.

the hot water to have descended from F, to G, the cold water in E, B, must be the heaviest, and, therefore, will hold the hot water back from entering the horizontal pipe G, B, so that if anything, the current must be from E, to B, instead of from B, to E. The method for surmounting this difficulty is as follows:—To erect a small cistern, as at M, let your flowpipe run into the cistern, as at P, per dotted lines, and connect the dotted line, pipe N, with the pipe at R; then your heating pipe, R, F, G become a return pipe, and take the cold small cistern, and perfect circulation w through the whole line of pipes. But o

must you neglect to put in the air pipe, R, and, if necessary, the air pipe, P; but I should remark that your cistern pipes will be all the better if they are close to the bend, F, as shown in Fig. 1,575. Of course smaller size pipes, say 2in. wrought iron or lead, will answer the purpose.

We have now seen sufficient of boilers; I will, therefore, now proceed to explain the fittings, and fitting up hot water work generally.

Steam Pipes and Small Fittings.

For the pipes I would never use more than 1in. wrought-iron barrel, or stout lead, or copper pipes and fittings throughout. Such iron pipes are illustrated at V, W and M, L, Fig. 1,591. A, is a bend; B, a spring; C, an elbow for

PIPE FITTINGS.

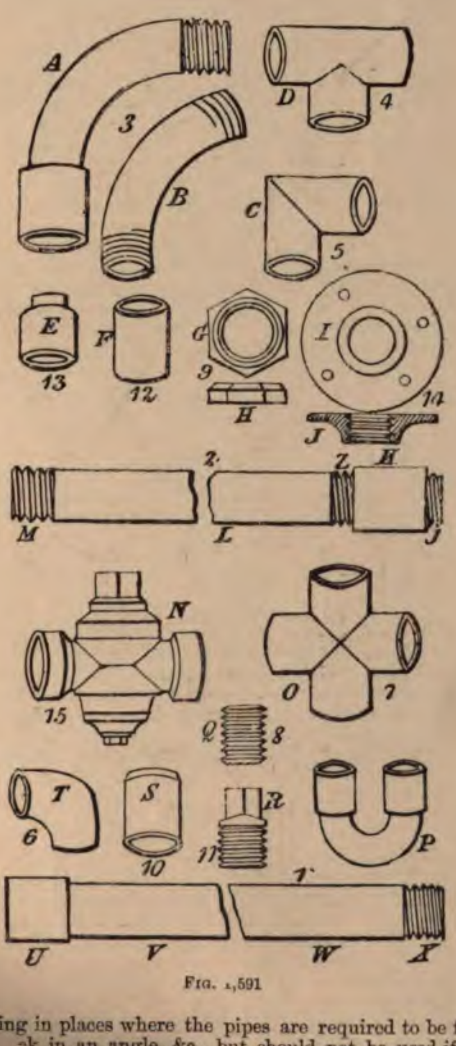


Fig. 1,591

working in places where the pipes are required to be fixed ...k in an angle, &c., but should not be used if you ... because they greatly retard ... all hot-water work is of great consideration. T, is a round-back elbow, which is much better than the square elbow. D, is a tee for the purpose of taking a cock or branch off, as at L, and J, Fig. 1,572, L, P, Fig. 340. O, Fig. 1,591, is a cross that is used in places where there are two branches coming off one pipe—a very handy fitting when two branches are wanted to come off the perpendicular flow pipe, and to go right and left of a floor. P, is a return which is scarcely ever used. Two bends, or a bend and elbow screwed together, answer its purpose. F, is a plain socket for connecting the ends of the pipes. E, is a reducing socket for reducing one size pipe to another, and may be had from 1in. to ½in., or even from a greater size down to ½in. Q, is a nipple for connecting two female fittings, such as the screwing of two sockets together, or for screwing an elbow on to a tee, &c. This nipple should be cut out of extra thick pipe, such extra thickness to be added to the outside. R, is a plug for stopping off a tee elbow, or the end of a socketed pipe, &c. Stop caps are made. These are nothing more than a socket with a blank end, as at S, Fig. 1,591. Sometimes this is made by half filling a socket up with lead, and hammering it well in, so as to cause it to expand laterally and to fill up the sides of the socket. When such is used, fill the socket with red lead paint and then turn it out, when the inside will be thoroughly painted; then stand it *lead downwards* to dry. Sometimes it will be best to tin the end, and solder round on the iron and lead; this is not good work, but answers a temporary purpose. Use a proper welded cap or plug; the other is only for a makeshift, or would be useful for gasfitting, &c. G, H are back nuts, plan and elevation. These are used to connect the pipes to cisterns, boilers, &c., and will be spoken of after the connector M, K. This connector is simply a *stout* pipe having a long thread, as shown at K, R, having a running socket K, with one end Z, nicely faced or turned. Now take off this running socket, and put on and run down the back nut, the *faced* side to face the *faced* end of the socket. See that there are no burrs on the face of the nut or socket. Run the back nut down first in order to make sure that it will run easily. Now put on the socket, the faced end to face the back nut, and this is a connector, the use of which is for repairing, &c., or for taking the pipes to pieces, &c. The back nut, which is somewhat enlarged and shown at Fig. 1,592, is to compress the grummet well up to the end of the enlarged

CONNECTOR

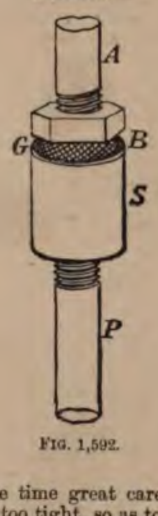


Fig. 1,592.

socket. At the same time great care should be taken not to turn the back nut too tight, so as to cut the grummet in

2B2

two, which is too often done, and left by the fitter when running pipes during the carcasing.

I may here give a description of the grummet, as, although it may appear an insignificant item, it nevertheless, in practice, is of great importance that it should be made with care to ensure sound work. Fig. 1,592 is an elevation of the connector when finished; A, is the piece of pipe whereon the running thread is cut; P, the pipe whereon the socket S, has been run from off the long thread to form and make the connection; G, is the partially compressed grummet, which is made with hemp or with the strands of twine properly saturated with red lead paint, and firmly but neatly wrapped round the pipe, the finishing end of the hemp, &c., running to a point, and finishing in the same direction as the screw or thread itself, or the grummet may be made by making a ring of hemp which must be firmly wrapped round in such a manner that it cannot spread too much in a lateral direction (of course such grummets must be made to fit the thread); R, is the back nut screwed down upon the grummet, with only just sufficient force to compress the grummet watertight into the crevice or thread space between socket and pipe. Sometimes a metal washer is used between the back nut and grummet, which prevents the grummet being cut by the turning of the back nut. I, J, Fig. 1,591, is a plan and section of a flange; this is used in places where back nuts cannot be employed.

For instance, they should be used on the tops of boilers, to be bolted on with three or four screws, so that the end of the pipe cannot go past the inside of the boiler, which will prevent steam room, or steam generating in the boiler, and often save the unpleasant noise before spoken of, viz., bumping or rattling occasioned by the steam going into the hot-water tank. Such a sound is often to be heard when the driver of a locomotive engine is sending his surplus steam into his tender to warm up his cold water, so that his engine may "contain" itself when on the road—*very handy for a long run.* N, is the stop-cock made of iron, but very little used.

I have now explained nearly all about these iron fittings, and will next proceed to show you the method of working them. First turn to Fig. 1,593. Suppose the connector

PIPE TONGS.

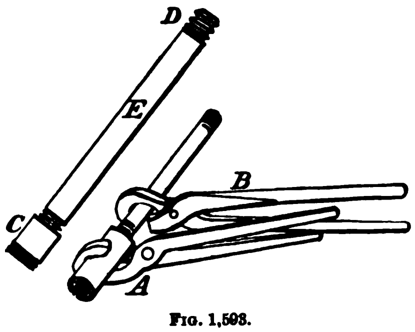


FIG. 1,593.

C, D is required to be cut, measure the exact length required, and place the pipe in the pipe vice as at A, Fig. 1,594, and in such a manner that the pipe cutter, Fig. 1,595, can be put on to work freely round the pipe. Do not squeeze the pipe down too hard in the vice so as to split or flatten it, but just sufficient to hold it, and to prevent its turning round. Now place the cutter on as shown at A, D. Fig. 1,595, and by turning the pin E, round, bring the wheel by degrees, and work it round the pipe. ...tle oil on the wheel and round the pipe to enable ...r to turn easily. Now keep the cutter quite perpendicular to the pipe, and steadily work it round round, at the same time, occasionally, with the pin tighten down the wheel until the pipe is cut through w the tool. It often happens that the pipe is burred on

PIPE VICE.

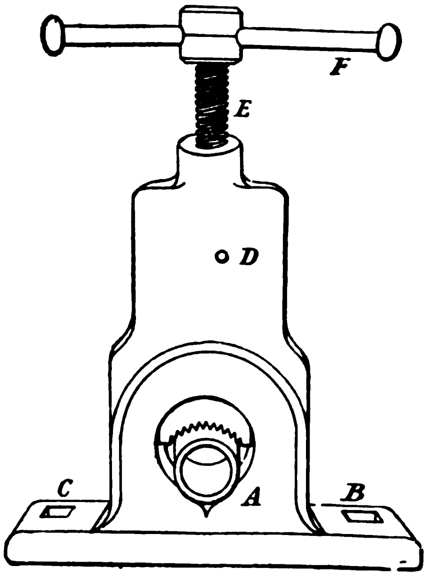


FIG. 1,594.

PIPE CUTTER.

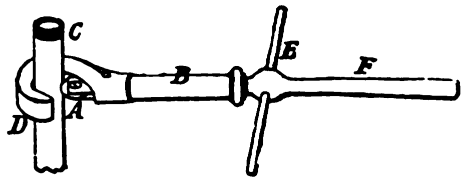


FIG. 1,595.

inside by reason of the cutter pressing these molecules of iron inwardly, which will interfere with the water-way. If this is required to be taken off, use a reamer, as shown at R, T, Fig. 1,599, which is turned with the key Fig. 1,600.

PIPE CUTTER (3 WHEEL).

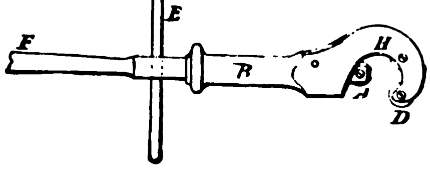


FIG. 1,596.

Should you require to cut a pipe when fixed in an angle such as for a repairing job, then this cutter may wheel cutter, as shown at Fig. 1,596. Her

you see three wheels which will cut in three places at once. This will enable you to cut round the back part as well as the front; but, for cutting pipe in the vice, the one wheel is best, because the flat part of the snout D, or nose of the cutter, Fig. 1,595, being flat, keeps the wheel perpendicular

PLUG TAP.

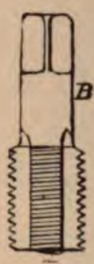


FIG. 1,597.

TAPER TAP.

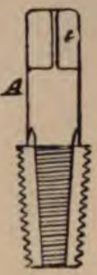


FIG. 1,598.

REAMER.

FIG. 1,599.

to the cut in the pipe, and so prevents the wheels from getting broken, viz., if the cutter should be roughly used, or tilted on one side, which is apt to be the case with the unskilled workman; besides the flat part of the cutter keeps the edges of the pipe down. Fig. 1,597 is a plug tap. Fig. 1,598 is a taper tap.

WRENCH.

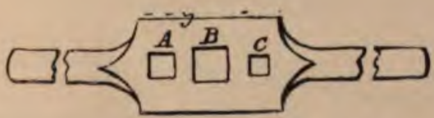


FIG. 1,600.

Should you require to cut out an old pipe, and have no such tools at hand, then, with a cold chisel and hammer, cut off, or rather split, the socket. Two hammers sometimes will do this, that is by placing one hammer at the back of the socket and hammering away at the front of the socket, and occasionally using the cold chisel at the end, trying your best to split it. You are sure to succeed if you

STOCK AND DIE (SOLID DIE).

FIG. 1,601.

try. Having cut your pipe, next begin to prepare for screwing. First wipe the face free from oil, to prevent the getting clogged, an[illegible] or 16in. bastard cut, flat [illegible] a thre[illegible] may be used) file down [illegible] smooth all round. These solid dies are the best sort, as they generally cut quickly to one gauge, and with a taper thread. Now place plenty of oil in the threads of the dies, and also upon the pipe; place the dies on the pipe and push hard and evenly, so that they may catch hold of the pipe, then gradually work them up the pipe, by turning them forwards and backwards occasionally, freely oiling the dies, so that they *cannot become dry or too hot*, to soften them, &c. Keep at this until the thread is of the desired length, which should be the length of the thickness of the dies. The thread should be, as before remarked, a little tapering, so that it may tighten itself as it screws up the pipe. This stock, if what is known as ½in. stock, may be fitted with ⅛in., ¼in., ⅜in., ½in. dies, sometimes only ¼in., ⅜in., ½in., and at other times ⅛in., ¼in., ⅜in., according as ordered. The next size is ½in., ¾in., 1in.; next, 1in., 1¼in., 1½in., and 2in. My sets run from ⅛in., ¼in., ⅜in., ½in. The next size is ½in., ¾in., 1in. The next, 1¼in., 1½in., 2in., made by the inventor, Cowley. I have also a set of the old diamond pattern, Fig. 1,602, but they do not get much used, as the

STOCK AND DIE (DIAMOND PATTERN).

FIG. 1,602.

men prefer the solid dies, which do not require half the labour nor time to work them; besides, the solid dies have a guide C, which insures their being put on parallel with the pipe, and therefore gets a straight threaded pipe; though, of late, the old-fashioned dies are fitted with this guide.

Screwing Iron Pipes with a Slide Cutting Tool.

This machine, for screwing large pipes, has a decided advantage over either of the former apparatuses, inasmuch, as with Fig. 1,603, a man can work the tool with the greatest of ease, and do good work at the same time. The invention is shown in action at Fig. 1,603, and consists of a strong wrought iron cylinder A, having a screw of 11 threads to the inch on the outside, on which the socket B, travels freely. A sliding tool or cutter holder C, is attached, and by means of a knob-headed screw, the tool or cutter is made to bear on the pipe, and when the cross handles are turned it travels up or down on the cylinder screw, A. A scraping tool or cutter is first used, to clean and reduce the pipe to the proper size, and afterwards the screw-cutting tool is used to form the thread. Cast iron collars are supplied with the machine, which fit the inside of the cylinder, A, and the outside of the various size pipes, to ensure their being central when the bolts, E, E, E, E, are screwed up to fix it. The bolts on base are for fixing machine on a bench or post. It is compact and handy, and can be packed with all accessories in a box 18in. by 20in. by 20in. It can be fixed by simply bolting it to a bench or a post. Although specially designed for works away from home, it is equally useful in a shop, one man being able to cut a screw on a 4in. wrought iron pipe as quickly as it can be done in a screw-cutting lathe with steam power. This tool is supplied by Messrs. Stroud & Co.

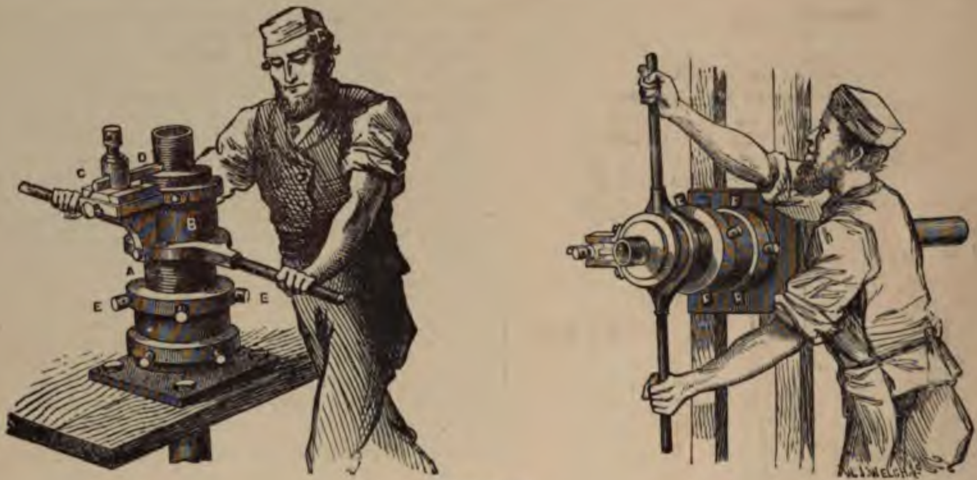


FIG. 1,603.

Adjustable Dies and Geared Screwing Machinery.

This invention is shown at Fig. 1,604, and possesses the following advantages :—First, it is a self-centreing pipe-holder, capable of gripping and securely holding *any size* tube with firm but equal grip, which prevents distorting or splitting the pipe, and is a desideratum of great value, as many pipes are rendered totally useless by their being squeezed up most unmercifully between the jaws of powerful vices, especially by the young workman whe allowed to run gas-pipes in building carcases. The ful thread can be obtained with this die direct, or the dies ca be adjusted to admit of the thread being partially cut, and therefore, admits tubes of almost any substance bein screwed when required. Another advantage is that it i self-centreing, and the pipes can be instantaneousl released or fitted. The machine is made by Messrs Winn. Fig. 1,605 is the same kind of machine fitted o stand.

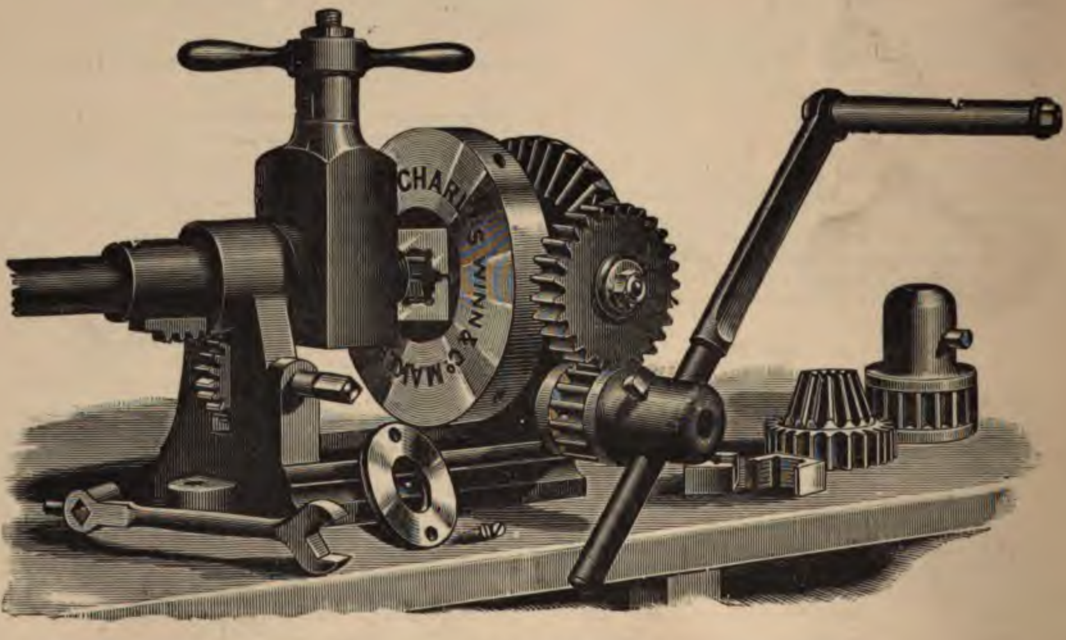


FIG. 1,604.

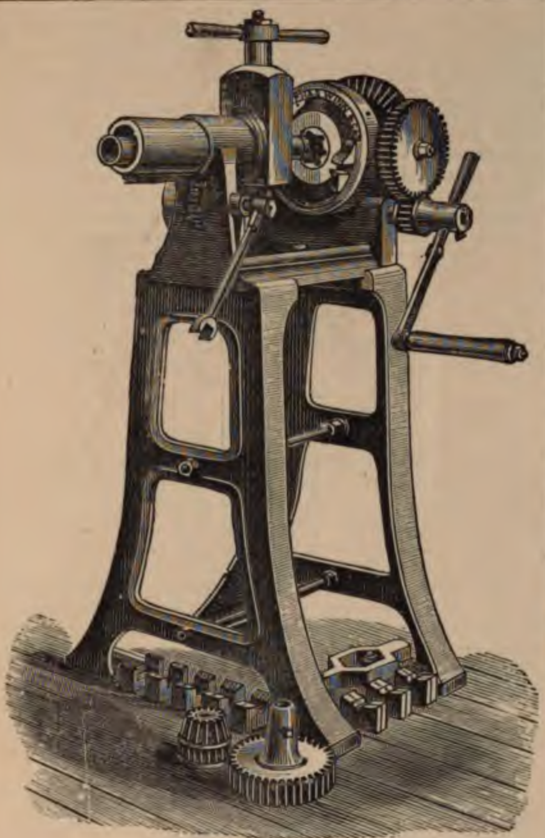
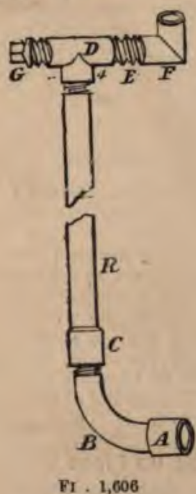


FIG. 1,605.

Pipe Fixing.

Having cut the pipe and thread on the same, next fit together one piece of 1in. barrel with a bend at one end,



FI . 1,606

and an equal tee at the other, the outgo of the tee to be fitted on the end of the pipe, the extreme length to be 5ft. 3in.; the one end of the straight way of the tee to be plugged, the other to be fitted with a nipple and elbow, and all as shown at Fig. 1,606. Now, it may happen that this tee will not screw on to your pipe, nor can you, perhaps, get the plug, G, to enter the tee socket, or elbow. If this is the case, the thread of the pipe may be burred, which is done sometimes by thoughtless persons dabbing down the ends of these pipes and sockets on hard substances, such as paving stones, &c. When this is done it will require the taper tap, A, Fig. 1,598, run down to open the thread of the socket or tee. This may be the case with the socket, &c., or it may be the end of the pipe which is burred; if so, then run the dies down to open the thread. Or the fittings may not be exactly the same size as the pipe; all this has to be considered, for, if the fittings are too small, the work will be increased; therefore they should be carefully selected, or had from the same maker as your pipes. Of course you know that a steam pipe is stouter than a gas pipe, so are the fittings in sizes proportionately. Fig. 1,597 is the plug tap for making running sockets, &c. Fig. 1,600 is a wrench for working the taps and reamer.

Screwing Pipes Together.

PIPE TONGS.

In order to screw these properly together, keep your pipes or fittings in as straight a line as possible, so that the threads may properly enter each other, and without getting on the cross, which, if proceeded with, will totally destroy the threads, and thereby will be sure to cause leakage. For screwing together 1in. barrel, &c., two pairs of tongs are required. These tongs should be 1in. and

FIG. 1,607.

FIG. 1,608.

$1\frac{1}{4}$in.; the 1in. to grip the barrel, R, Fig. 1,606, the $1\frac{1}{4}$in. to grip the socket C, A, and the tee at 4 and F. These tongs are illustrated at Figs. 1,607 and 1,608, which show them placed for screwing up the socket and pipe. They are also shown at A, B, Fig. 1,593. B, is put on to unscrew the pipe, and A, to unscrew the socket. If the socket is required to be screwed up, reverse the position of the tongs by turning them upside down.

UNIVERSAL TONGS.

These tongs are shown at Fig. 1,609, and will be readily understood from the drawing. A, is the nose too[illegible]
J, the grip jaw, also toothed at the inner [illegible]
formed on the same piece of material as the [illegible]
The nose is centred at the pin B. It will be se[illegible]
a piece of pipe is placed between the jaws, an[illegible]
pulled up, as indicated by the arrow lines, P, [illegible]
if the nose, A, be pressed towards the jaw, J [illegible]
pin, B, be properly adjusted to suit the size [illegible]

grip the pipe accordingly. Fig. 1,610 illustrates a very handy nut wrench, which will take in almost all sizes. It is especially handy for old work.

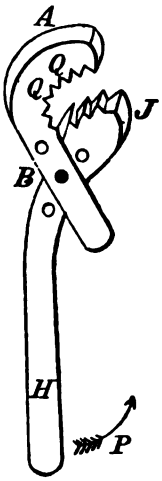


FIG. 1,609.

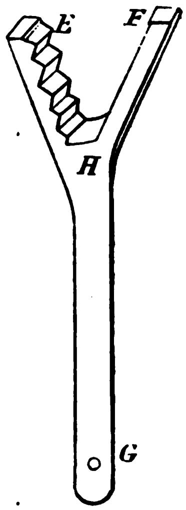


FIG. 1,610.

PARROT-NOSE TONGS.

These tongs for their action also depend upon the same principle as the universal tongs, the difference being that the jaw, J, works through the jaw, A, in a more circular direction, as may be seen at J, K, Fig. 1,611. These parrot-nose tongs are handy for taking out to do jobbing work, as they will fit many different size pipes. They

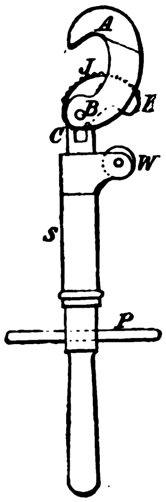


FIG. 1,611.

sometimes have a cutter wheel, W, which saves carrying two tools. There are scores of others of this class; but for good hard work I prefer the old pattern tongs, Figs. 1,607 and 1,608. Sometimes it will so happen that you have not tongs with you, and that you want to unscrew a pipe, but you have a good screw wrench, as shown at Figs. 1,612 and 1,613, which is a constant companion of the jobbing plumber. (I say jobbing plumber not out of any disrespect to him, for I consider a good jobbing hand to be the most practical amongst us—that is, if he knows his trade; but unfortunately many jobbing plumbers are to be found who are incapable of doing good work when called upon, and who are the means of sadly disgracing our trade generally.) You will no doubt say that the wrench is useless for such work; but this is not so—it is of great use, and I will show you how to make it

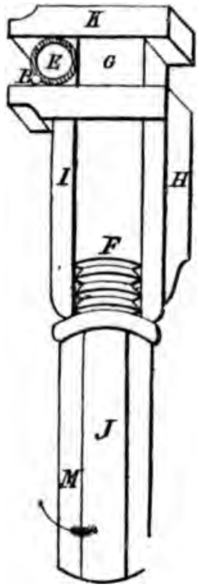


FIG. 1,612.

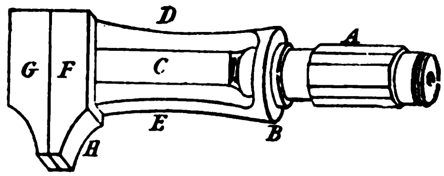


FIG. 1,613.

answer very well on a pinch. Screw the wrench to fit the pipe loosely, now get a round pin of iron or steel, such as a small piece of rat-tail file, or a piece of $\frac{1}{8}$in. or $\frac{1}{4}$in. iron wire, &c., and place it by the jaws of the screw wrench and side of the pipe, as shown at the round white speck, B, Fig. 1,612, in just such a manner that this pin will firmly grip between the jaw of the wrench and pipe, and so that the more you pull the wrench round (in the direction indicated by the arrow, M), the tighter it will become, and you will find no difficulty in unscrewing the pipes. You should be careful at this work, otherwise, if you go incautiously to work, it may slip and hurt you.

Screwing up Pipes with Cords.

Sometimes it will happen that you will want to screw up a pipe when, perhaps, you have neither screw wrench nor pipe tongs; when such is the case you may get over the

difficulty with a simple piece of cord and lever, as shown at A, B, D, F, Fig. 1,614, the cord being put upon the pipe in such a manner that the fulcrum part of the lever (at F) will take a bite upon the cord, and so prevent it from slipping round the pipe. Of course, the cord should take two or three turns round the pipe, which will cause extra friction to come into service.

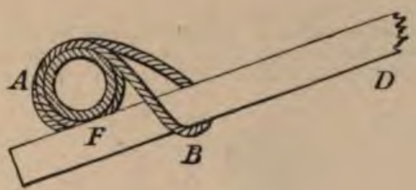


FIG. 1,614.

Having got so far, now I require you to fit me up some pipework as illustrated at Fig. 1,615. This is first a piece of pipe screwed into the stopcock as at A, B; C, is a bend; E, a short length of main; F, S, a cross; G, is a stopcap and nipple; H, is a branch; I, is an elbow; J, the main continued; K, a tee to branch off at K; L, a reducing socket fixed with a nipple on to the tee, K. Now at this last point there are two fittings thrown away simply because you wish to reduce the main. This should be properly reduced by a reducing tee, that is, by ordering a tee as follows:—One 1in. tee reduced to ¾in., 1in. out, that is to say, Q is 1in.; O, is reduced to ¾in. and the out K, is

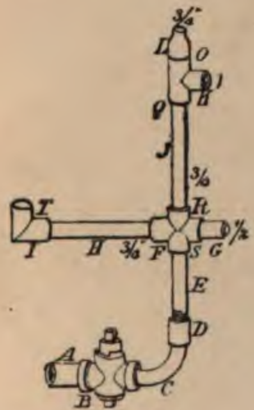


FIG. 1,615.

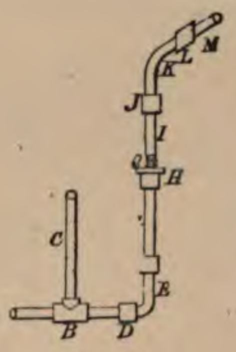


FIG. 1,616.

1in. But suppose it is required to be a straight run of main pipe, that is for L, and Q, to be equal, and also the outlet K, then order an equal tee. But suppose you require to reduce the branch at K, to ½in., then order the tee as follows:—One 1in. tee ½in. out. Crosses may also be had in the same reduced style. Suppose G, to be a ½in. branch, F, a ¾in., and R, ½in., then order as follows:—One 1in. cross to ¾in., and ¾in. and ½in. outs. Elbows may also be had reduced as required. Now fit up Fig. 1,616 with one short length as at M, one spring as at K, a connector to be fixed at I. H, is the back nut, which I will further explain. The back nut should be run back up the thread Q, of the pipe, and then the socket may be turned back up against the nut. Now, for the connection, screw the socket off the pipe I, on to the red lead painted thread of the pipe G, and screw it up firmly, but not too tight, so as to cause the socket to split. Now get some long fibred hemp, and pull it out nice and straight, paint it with red-lead paint, and wrap a little round the thread of the connector, and close up to the *faced* end of the socket, so as to form a grummet or washer. Next bring down the *faced* side of the back nut and screw it tightly on the end of the socket, but not so tight as to cut and spoil the grummet or hemp washer, but just tight enough to make it sound. Now screw on the bend E, and the pieces A, B, C, D.

You will notice that it will be a very easy matter to disconnect the pipes at I, simply because you have a running socket on the pipe, which is kept sound by the grummet and back nut H.

Now that you have seen the various kinds of fittings I wish you to make your own bends to save time and cost of the ordinary fittings. For this you will require a small portable forge, such as is illustrated at Fig. 1,617. These

FIG. 1,617.

small forges will be found very handy for all kinds of hot water and gas work (except when galvanised iron is to be used, then the forge must not be used unless the iron is to be afterwards galvanised). The bends and set-offs, such

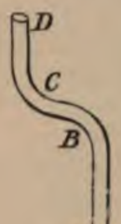


FIG. 1,618.

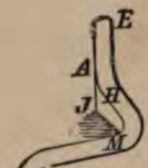


FIG. 1,619.

as shown at Figs. 1,618 and 1,619, may be made in half the time, for here a lot of screwing and cutting is done away with, and the pipe may be bent like so much leaden pipe.

When bending with the forge, do not attempt to do it while the metal is too hot, or too cold. When you have acquired the right heat, which, after a little practice, you will readily be able to do to a nicety, place the pipe to be bent between the jaws of the vice (Figs. 1,620 or 1,621), and

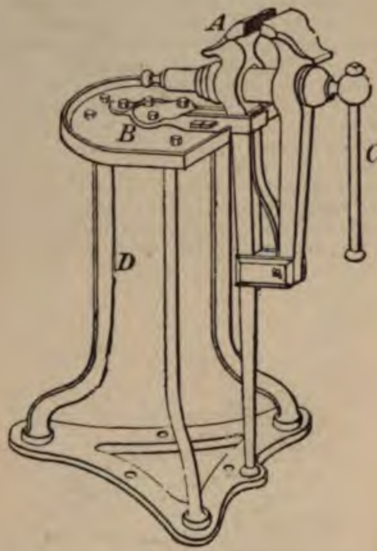


FIG. 1,620.

just tight enough to keep it from spreading laterally, and as at B, Fig. 183. Pull the barrel round to the desired angle. If after a little practice you find some of your pipes flatten at the throat without spreading, it is a proof that the material is too light. For such work, light pipe will

FIG. 1,621.

not stand the pressure put upon it, and consequently it flattens or indentates at the throat, as at X, Fig. 183. If the pipe is rotten, or if bent while *too hot*, it will break away at the back.

To prevent the bend being too long when the hea long one, pour a little water from a ladle, or other round the outsides or the outer ends of the heat. hardens the iron, and will prevent it bending except desired point.

Plumbers' Universal Vice.

This vice is shown at Fig. 1,622, and will be r understood by the engraving. I may add that it i most useful vice I ever used. As can be seen it will

FIG. 1,622.

pipes of ordinary size; it answers as a general vic almost everything which a plumber has to do, a wherever used, much liked. It is made by Messrs. H Ward & Co.

Pipe Bender.

The occasion frequently arises in the shop to do mo less bending of pipes, and yet few establishments are

FIG. 1,623.

vided with as simple and inexpensive an arrangemen here illustrated at Fig. 1,623. By means of this fix

much time and patience can be saved. It consists of a casting about 18in. long, tapering from 7½in. at the top to 9¾in. or 10in. at the bottom, with ears and shoulders at right angles, by means of which it can be fastened either to a post put up for the purpose, or to one of the pillars of the shop. These shoulders are clearly shown in the diagram at A, B, E, F, and H. A series of holes are cored in the casting, with rounded edges and a rounded corner, against which the pipe bears, which will give the required bend, owing to the radius of the end of the pipe held by the operator. The pipe to be bent can be inserted at either side of the hole, the holes being made of such diameters as are best suited to the work.

Sometimes the plumber makes himself a pipe bender with a kind of pulley wheel fixed at the end of pipe or tube opening, through which he pushes the iron pipe, then pulls the pipe by its other end against the bottom and hollowed part of the wheel, and in this manner he can bend several size pipes with one machine.

N, M, is properly trapped, and then taken direct into the return pipe at the nearest point to the boiler, or still better direct into the boiler, and this pipe together with all stopcocks, and other water passages larger than the draw-off, then the chances will be that you will not get hot water with the cold. I, is the air or steam pipe taken to the top of the house. The hot-water supply pipe H, to the best bath is with a tee taken off this air pipe, also the hot-water pipe I, J, K, Q, R, A, B, and G, to supply the washbasin, scullery sink, servants' bath, &c. In this section may be learnt the whole system of hot-water work. By reference to the manner in which the draw-off pipes are taken off the top part of the tank, it will be plain that it cannot be emptied at any of the draw-off cocks, and therefore will be the best system to adopt (should the water supply fall short through frost, &c.), because there will always be a good supply to keep the boiler from becoming dry. Some plumbers use a dead weight or other safety valve on the top of the boiler or tank to open should there be any extra pressure accumulated within the boiler or tank (see Safety Valve).

Fixing or Fitting up.

Let us now look over the section of a house which has been fitted up on one of the most approved principles. For this refer to Fig. 1,624. Here we have a close kitchener, marked 45 and 46, with boiler at back, as shown in the working drawings at 66, and at R, F, Fig. 340, and also at Figs. 1,578, 1,579, and 1,572. In this last engraving G, R is the return pipe, bringing the cold water from the *bottom* of the circulating *tank* to the *bottom* of the boiler, also see Figs. 339 and 340.

In Fig. 1,624 the HOT WATER TANK is fitted at the bottom of the house and near to the kitchener. This often saves a long length of pipe. The cold water supply pipe L, M, N, Fig. 1,624, is brought right away from the top tank, and as shown with a stopcock at M, and also a trap to prevent the hot water rising through this supply pipe. But notice if the hot water tank is above the bath as marked by the dotted lines at 36, Fig. 1,624, and if the cold supply pipe to bath, &c., as at 4 is, as shown, taken off the pipe N, then you will be likely to get hot water into your cold when drawing, especially if any part of the pipe between the cold-water cistern and branch be cramped, or a Rotherham stopcock fixed thereon, *unless the return of the hot water be properly checked with a proper check valve.* These valves I do not like as, however good they may be made, they corrode or rather fur and become set, and therefore dangerous or useless. In fact, when the hot-water tank is fixed above a cold draw-off cock, then no draw-off should be allowed to be taken off the cold water supply pipe to the hot-water tank; that is, if the tank is fixed at a higher level. The cold-water pipe 4 in that case should be run from A, Q, Fig. 1,624, to A, K, and branched on at this point, or brought direct from the cold-water cistern. But if the cold-water pipe

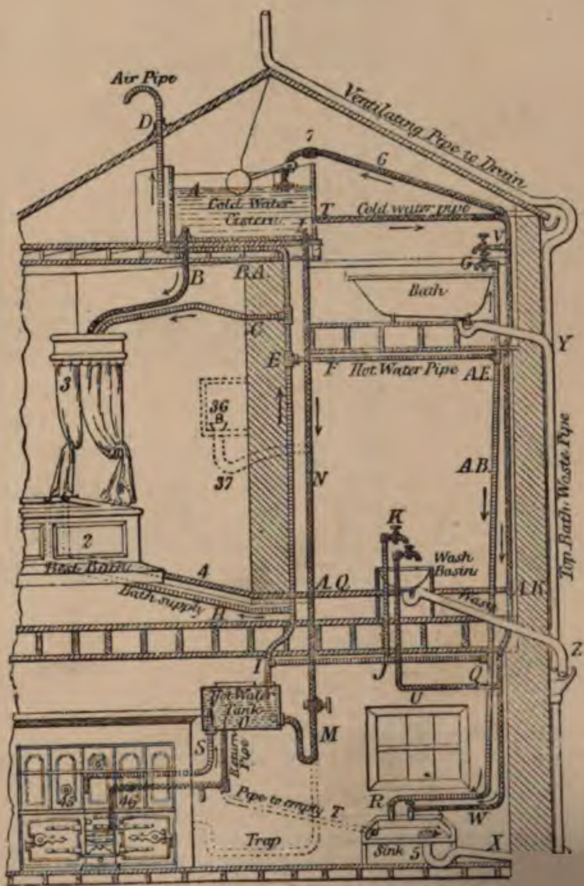


FIG. 1,624.

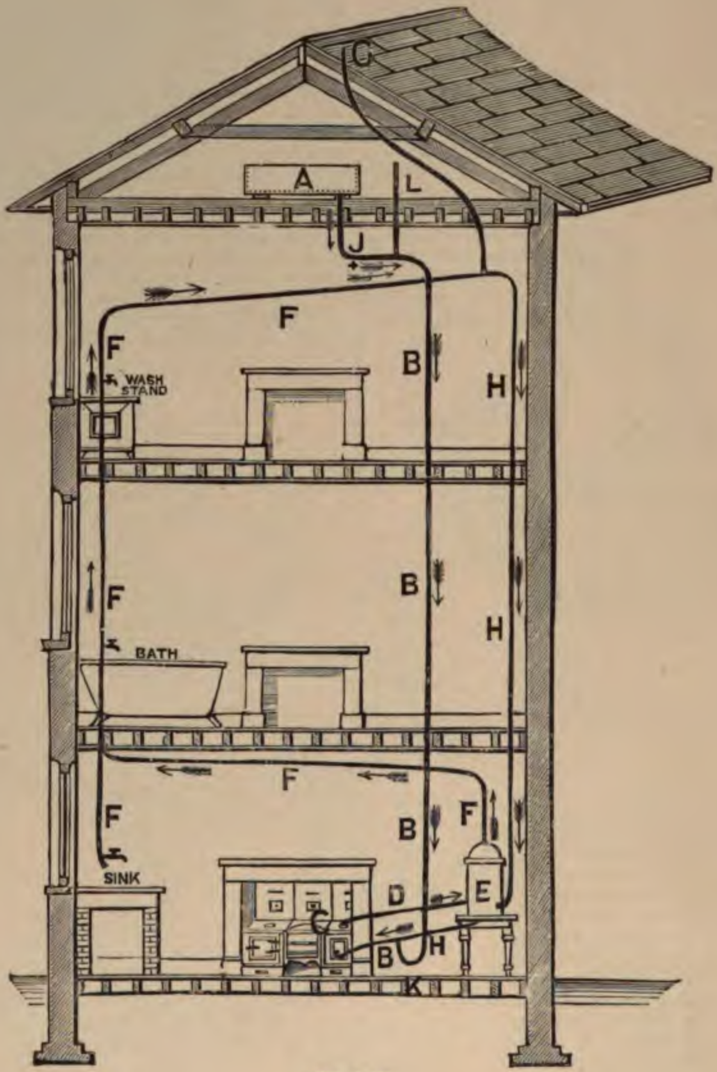


FIG. 1,625.

Fig. 1,625 illustrates the whole system of hot water circulation, with the circulating tank E, at the bottom, fitted up by Messrs. Braby.

Here, at E, F, F, F, you see a second circulation pipe travelling, as shown by the arrows, F, F, and H, H, and in such a manner that you can draw hot water at any point without having any stagnant or cold at the first portion of drawing of the water. This also, to a certain extent, acts as a heating apparatus.

The parts are as follows:—A, the cold water tank; J, a stopcock; L, an air pipe; B, B, B, B, is the cold water supply pipe, branched into the return pipe between boiler and circulating tank (I should prefer to see this cold water pipe to go direct into the boiler).

Select the materials necessary for such a job as shown at Figs. 1,572 or 1,624.

I have said sufficient about the boiler, and have only to add that you should always have it fixed to heat the water as quickly as possible.

Circulating Tanks.

Now for the size of the circulating or HOT WATER tank, which is shown at TANK, Figs. 335 and 1,626A; also as fixed under different conditions at HOT WATER TANK, Fig. 339, and circulating TANK, Figs. 1,572 and 1,578, also at HOT WATER, Fig. 1,624.

I have shown these tanks as fixed by myself under different circumstances to suit the place and class of work, and I should state that they are known by all the above names. One thing must be borne in mind: let this circulating tank be sufficiently large for the quantity of hot water required to be drawn at each time. Say that you have two baths, as at Fig. 1,624, each requiring 25 gallons of hot water, and that they may be wanted at one and the

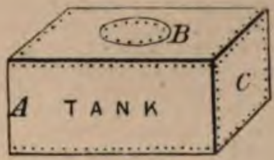


FIG. 1,626A.

same time, then you will require the tank to hold more than 50 gallons. But suppose that there be a constant demand for hot water at the sinks, &c., then, in order to keep up a sufficient supply for the baths, you must have a larger store tank for the hot water. Notice.—All hot water tanks when exposed should be protected from cold with hair felt; in fact, all pipes should be so protected.

Situation of Hot Water Tank.

The situation of a hot water tank should be carefully studied by the fitter, as when this tank is fixed (as shown at Fig. 339) a long distance from the boiler, a large quantity of heat, proportionately to the length of pipes, is given off, as would be the case in systems of warming by hot water. The variation of the amount of heat lost, of course, being inversely, as the mass divided by the superficies; for instance, suppose you have a 1in. pipe whose length is 5ft., and another whose length is 60ft., there will be in the 60ft. length twelve times as much cooling surface as in the 5ft. length, and this being multiplied by 2 (the flow and return pipe) will make a wide difference in the time the water takes to boil.

Then, again, there is another reason why the hot water tank should be fixed close to the boiler, and that is, in the 60ft. distance there will be exactly twelve times the amount of friction to that of the 5ft. length, and these two items, to say nothing of the difference in the quantity of pipe, are of no small consideration in all hot water fittings.

Measurements of Pipes, &c., without waste.

Now measure the lengths of pipes required throughout the building. Say that the distance between the boiler and tank, as at Fig. 1,624, is 12ft., here you will require 9ft. twice, say 18ft. of 1in. steam barrel, and four 1in. connectors, 12in. long, with six 1in. back nuts, and four 1in. bends. These bends are generally from 5 to 6 inches long from the external angle, so that the two bends will make, say, 12in. in length, and, therefore, will reduce the length of pipes, which otherwise must have been 10ft.

I am ordering these lengths as though they would absolutely come in without cutting, but in practice (unless as before stated *great care* is taken in your measurements) you may find it necessary to cut them to suit your work; but, if you are very careful in taking your "dead lengths" or measurements, and fixing your tanks, &c., you may work this way with advantage to yourself by saving labour. N.B.—At times it will be best to cut the holes in the bottom of your tank, and sometimes in your boiler, after you have "run" your pipe, because then you can go an inch or two either way, and according to your lengths of piping. For instance, from the return pipe bend (Fig. 1,624) to the bottom of the tank may be 2ft. Now, in such a place you will require a connector 18in. long and one bend; but on this pipe should be fixed an emptying tee, or it may be as shown at PIPE TO EMPTY, which, of course, must be allowed for; then the length of pipes or connector should be accordingly, say 1½in. less, unless you can work in a tee without a bend, which is not so good for the free flow of the water. For connecting the flow pipe to the boiler you will require a flange as shown at J, I, Fig. 1,591.

Cutting Holes in Tanks.

This is generally done with the diamond-pointed chisel by first marking the size of the hole, and then go round it with the point cutting it nearly through, then, finally, for about half way round, the remainder can be knocked out.

Drilling Holes in Tanks, &c.

Sometimes it will be necessary to drill holes in the cisterns or tanks, especially cast iron. When this has to be done a ratchet brace may be fixed under a piece of quartering fixed below the flange on the top, or in many other ways, or a drill may be employed, as shown at Figs. 1,238, 1,239 and 1,240.

Let us assume that the former measurements are correct, simply for convenience of making out our list of things required. Now measure the length of the draw-off and air pipe, I, E, D, Fig. 1,624. Say that this is 40ft. from the top of the tank to the top of the house, but on this pipe there are several draw-offs, &c., as shown at C, E, I. Say that it is from the tank to the first draw-off, I, J, 18in., with a set off above of 12in. Here you can use one connector 16½in. long, one tee, and two bends, as shown at

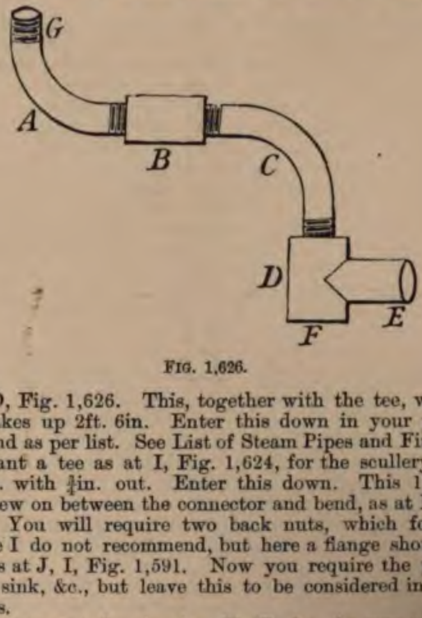


FIG. 1,626.

A, C, D, Fig. 1,626. This, together with the tee, we will say, makes up 2ft. 6in. Enter this down in your pocket book, and as per list. See List of Steam Pipes and Fittings. You want a tee as at I, Fig. 1,624, for the scullery sink, say 1in. with ¾in. out. Enter this down. This 1in. tee will screw on between the connector and bend, as at I, Fig. 1,624. You will require two back nuts, which for this purpose I do not recommend, but here a flange should be used, as at J, I, Fig. 1,591. Now you require the piping for the sink, &c., but leave this to be considered in a few minutes.

When running the air pipe, D, E, &c., be sure to le[ave] this tee with ¾in. out, and fix a short length of p[ipe] suitable to reach up to the first branch, as at J, and t[urn] the tee the right way pointing toward J, for if you do n[ot] you will loosen the joints if the tee is afterwards disturb[ed]

Now, if your set-off is, say, 10in., two bends may be used, or, if less, one bend and an elbow, as shown at A, B, C, Fig. 1,627. Enter them down. Now you want a tee, say an equal, that is equal bore through, and equal bore out for your bath supply, as at H, Fig. 1,624. Put that down. Now, say that you require 10ft. for supply to bath. Enter this down 10ft. of 1in. pipe. From the second tee to the third is, say, 20ft., let it be two 10ft. lengths. Enter this; also another tee, say an equal, at E. Now measure the length of pipe to the next tee, C; say this is 2ft. 6in. Enter this down with another equal, or other tee. Now measure from the last tee to the bend, A, B. Say this is

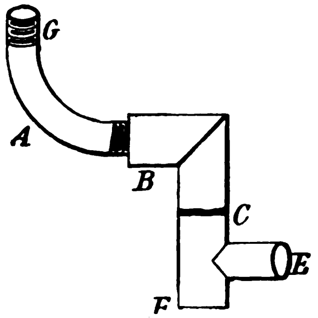


FIG. 1,627.

4ft., say the bend is 6in., then you require a length of pipe 3ft. 6in., and one bend. Here your attention is required relative to the expansion of metals, for between I and the bend A, you have 30ft., which will, as the heat increases or decreases, expand or contract, according to the temperature of the water, and, therefore, you must keep all branches and the end of pipe at A, B, free to move; allow, say, 1in. or 2in. each way. Now measure from this bend, A, B, to the next; say it is 10ft. 6in. Then here you require 9ft. 6in. length and another bend. The above measurements should be taken, and each piece marked as from No. 1, and according to a rough drawing.

Next you require, say, 13ft. length of pipe, which will make, with bends, connectors, and tees, say 40ft. (It will be best to finish this pipe with an acute or return bend as at D.) Now measure the branches; say that the length from E, to A, E, is 12ft. (but I should prefer a connector to be put in this length). Enter this. Next enter 1in. equal tee. From this tee to cock, G, is, say, 3ft. 6in. of 1in. pipe, and 1in. elbow. Enter this down.

Now the return pipe, A, E, to Q, thence to pipe, M, (answering as the second flow and return, as in Fig. 1,625), which should be put in, but is more often left out; this pipe may be of ¾in. or even ½in., but, for our purpose, say, 1in., and, if so, order your fittings accordingly. This pipe prevents the water getting cold in the whole line of pipes between E, and A, E, A, E and Q, Q and I, because this is simply a return pipe; its length is, say, 21ft. Here order, say, one 10ft. and one 11ft. length. At the bottom you require a tee, as at Q; this is 1in. to ¾in. and ¾in. out tee, which should be so ordered, because the pipe, J, I, Q, is ¾in. Enter this tee down. Now you require the ¾in. pipe, Q to J; say this is 6ft. Enter this down, 6ft. of ¾in. pipe. Next you require a ¾in. with, say, ½in. or ⅜in. out tee for the wash basin as at J; enter this down. Now you require another 6ft. of ¾in. pipe and one ¾in. conductor 12in. long, with back nut, for the purpose of connecting the pipe, I, J; enter this down. Next you will require the pipe from Q, to the hot-water cock, R. Say this is two 6ft. lengths of ¾in. pipe, one ¾in. bend, and one ¾in. rounded back elbow, as at R. Enter this down. Now measure the pipe J, K, to wash basin, which is, say, 4ft. of ½in. or ⅜in. pipe, and one ½in. or ⅜in. elbow. This is the last to enter, unless other branches are required.

Testing Boilers, Pipes, Cylinders, Tanks, &c.

Now suppose you want to test your work; then do so with one ¾in. cock, R, as placed over the scullery sink, and order plugs for all the other draw-offs, not forgetting one for the emptying pipe, P, which I need not say would be best fitted with a ¾in. stop or bib cock with square head, and, if a cock is used, order a tee for the pipe P, accordingly; say three 1in. plugs, one ½in. ditto, which should be taken out after the pipes have been tested.

Sometimes it will be necessary to use a tester, which is shown at Fig. 915. This is one of Messrs. Bailey's testers. The method of working it is to simply connect the tube and nipple to the lowest branch, say at the sink branch, at R, Fig. 1,624, and then pump the pipes, &c., quite full of water, right up to the top of the air pipe (of course the cold water supply must be shut off), which must be plugged, you can then put what pressure you consider necessary upon the work, which should be about three times the amount which would be on the boiler when at work, viz., supposing the pressure in the boiler to be 70ft., then put 210ft. pressure on your gauge. If you have no testing pump, fill the pipes by pouring water into the cold water pipe in cold water cistern till quite full, and let it stand for a week or so, and notice if it keeps its level.

Let us now examine our book for the quantities, in order that we may see what the job will cost for the ironwork, which, although I have shown the method of entry, I do not pretend to infer that the money will be anything near correct, as it is merely put as an example of entry, and if entered as here shown it will be readily understood by those in the offices having to do with pricing work, &c.: this is a matter of no small consideration.

COPY OF ENTRY IN THE NOTE BOOK.

STEAM PIPES AND FITTINGS.

No. of Pieces.	Lengths. ft.	in.	Size. in.			ft.	in.
2	9	0	1	Steam barrel	=	18	0
1	9	3	1	,,	,,	9	3
2	10	0	1	,,	,,	20	0
1	3	0	1	,,	,,	3	0
1	9	6	1	,,	,,	9	6
1	13	0	1	,,	,,	13	0
1	12	0	1	,,	,,	12	0
1	4	0	1	,,	,,	4	0
1	11	0	1	,,	,,	11	0
1	10	9	1	,,	,,	10	9
				Total length	=	110	6

At 1/0 per foot, £5 10/6.

1	5	0	¾	Steam barrel	=	5	0
1	6	9	¾	,,	,,	6	9
2	6	1½	¾	,,	,,	12	3
				Total length	=	24	0

At 0/9 per foot, 18/0.

1	4	0	½	Steam barrel	=	4	0

	£	s.	d.
At 0/6 per foot,	£0	2	0
	0	18	0
	5	10	6
	£6	10	6

FITTINGS—CONNECTORS.

No. of Pieces.	Lengths. ft. in.	Size. in.	s.	d.
4	0 12	1	6	0
1	0 16½	1	1	6
1	0 12¾	¾	1	3
			8	9

BENDS.

			s.	d.
1	0 1		1	6
4	0 1		6	0
2	0 1		3	0
1	0 1		1	6
1	0 ¾		1	3
			13	3

The above is taken from the job to be done; but if taken off a drawing, you can count all your 1in. bends off, and say, 8 1in. bends, 1 ¾in. ditto, and so on.

BACK NUTS.

			s.	d.
6	0 1		3	0
2	0 1		1	0
1	0 ¾		0	4
			4	4

FLANGES.

1	0 1		1	9

TEES.

			s.	d.
1	0 1	¾in. out	1	3
1	0 1	equal	1	3
1	0 1	,,	1	3
1	0 1	,,	1	3
1	0 1	,,	1	3
1	0 1	¾in. with ¾in. out	1	3
1	0 ¾	with ½in. out.	1	0
			8	6

(Here again a drawing will be useful to count the tees.)

ELBOWS.

			s.	d.
1	0 1		1	2
1	0 ¾		0	10
1	0 ½		0	8
			2	8

I may add that on a large job it is often best to order the material as follows. Supposing you want 1,500 or 1,600ft. run of 1in. pipe, or otherwise barrel, order, say—

No.	ft.	in.		ft.	in.
50	10	0	=	500	0
20	9	0	,,	180	0
6	9	6	,,	57	0
10	8	6	,,	85	0
20	8	0	,,	160	0
10	6	0	,,	60	0
5	5	9	,,	28	9
5	5	6	,,	27	6
12	5	0	,,	60	0
12	4	9	,,	57	0
12	4	6	,,	54	0
12	4	0	,,	48	0
12	3	9	,,	45	0
12	3	6	,,	42	0
12	3	0	,,	36	0
12	2	9	,,	33	0
12	2	6	,,	30	0
12	2	3	,,	27	0
12	2	0	,,	24	0

or just what you may think will suit the job, you having measured it off roughly.

SUNDRIES.

1 Sixty-gallon galvanized hot-water tank, with screw-on cover, as at Fig. 335; HOT WATER TANK, Fig. 1,624; or E, Fig. 1,625, and Fig. 1,626A.
1 Four-gallon lap-welded boot boiler, ⅜in. thick, with manhole, as at A or B, Figs. 1,562 or 1,563.
1½ Pint of boiled oil.
3lb. of red lead; 2lb. of white lead.
1 Knot of tow.
2lb. of waste.
1 Pint of sweet or other lubricating oil (*not linseed*)
2 15in. Bastard cut taper files with handles.
1 12in. Rat tail file with handle.
1 1in. Full-way gun-metal stop-cock, with spanner (a gland cock will be best if much pressure is to be upon the cock—viz., say from 20ft. upwards).
Say 14lb. of 3in. and 4in. wall hooks, and 7lb. of 3in. and 4in. pipe hook.

In the above manner enter all your odds and ends which may be required for the job, including what *tools* you may require. This is what is known as the out entry, and when the job is finished, make a similar entry to the shop, which is known as the shop or in entry.

Here you get the materials used on the job, and the loss upon your tools, &c. You should sign your book at each entry *with dates*.

Then, as to fittings (if for a large job), take, say, a dozen or two extra different size tees, bends, elbows, plugs, connectors, flanges, &c., suitable for your work. Of course you can judge within a trifle. Then, again, there is another reason why you should adopt this style: that is you may see a chance of working in a fitting to a great advantage by way of saving time, &c., such as using a reducing socket and a short length of pipe to work in a bend or an equal elbow should you not have a reducing elbow, or you may use a reducing socket with nipple and tee and such like, but never use a nipple where it can be avoided. There are many reasons why a good stock of fittings should be kept in a shop or on a job. Of course, I may add, that, in order to get at the cost of a job you must adopt the exact mode of measurements (allowing about 10 per cent. for waste on pipes) and the style of taking the items, otherwise you would be all at sea. Allow for a few extra fittings, and for such things as paint, red lead, pipe hooks, use of tools, cartage, &c. You must also know what your labour is to cost, which, of course, when I see the job, I know myself; but, as circumstances alter cases, it is much the best to leave it to those who have to do with the estimates and work, for it is possible at one time to run 1,000ft. of barrel, bends, and fittings, &c., whilst at another time you could not run 50ft. For instance, you may have to run intricate work, every piece of which may have to be cut, bent, or full of fittings and connectors, whilst at other times you may have a straightforward job with plenty of latitude, and so scarcely have to cut and screw a pipe, and notice, when such work has to be done in new houses, that you select a seasonable time to run your pipes during the carcasing of the building, so that they may be run with an advantage, and up proper chases and casings, and in such a way (if price will permit) that the whole can be readily unscrewed for repairs, &c., viz., use connectors with proper judgment, *and take particul[illegible] that all your pipes are kept well away from the [illegible]* but as near to the other cold-water pipes as [illegible]stances will permit, to keep them from freezing.

FIG. 1,628.

Brass Work. Lead Work, Bath Work, and Bath.

I shall assume that you have read my works on joint making, and are thoroughly acquainted with the running of lead pipes and all such supplementary work: therefore, I shall now introduce to your notice a few baths. The first and best is a thorough good copper, properly shaped and cut as per my lines on geometry and well enamelled, such as illustrated at Fig. 1,628 or Fig. 1,629. This is generally made with the two ends cut and seamed as at E, F, the two sides separate, and the bottom with a sunk well W, B, covered with a strainer with sufficient holes to well fill your outlet pipe as shown. In the bottom of this well, as at B, P, is soldered a piece of lead or copper pipe to connect on to the waste cock or valve. Some plumbers branch all their pipes—namely, hot-water and cold-water—into this pipe, and so make it to answer the purpose of filling and also of emptying the bath. but this is not a good plan, because there is apt to be some little dirty

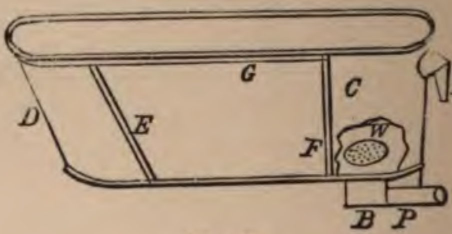


FIG. 1 629.

water always left in the well or short length of pipe, which will, of course, mix with the incoming clean water. The best method of filling the bath is by placing the pipes at the top, as at H, Fig. 1,630, &c. Here the cocks are shown as fitted upon the

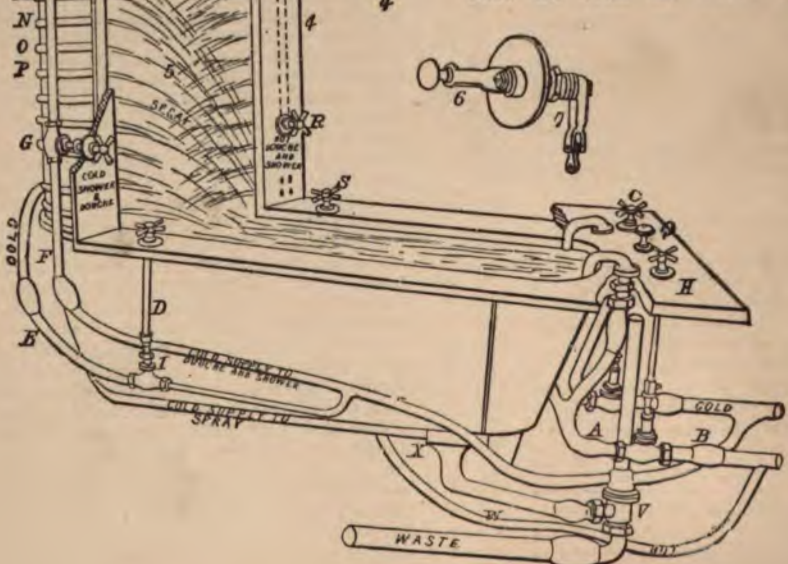



FIG. 1,630.

most approved principle (save and except the class of cocks), and as ordered to be done by most of our metropolitan water companies. W, is the waste-pipe leading from the well X, to the waste-cock, or rather in this case to the valve V; it then goes away by the pipe WASTE. A, is the lead pipe to convey the hot water to the top part of the bath, where it is allowed to pass through well-finished brass

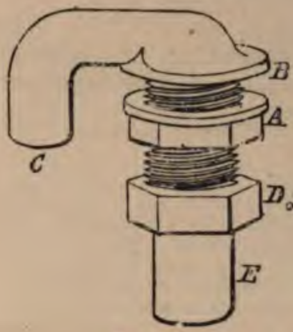


FIG. 1,631.

swan-neck nosings or spouts, the enlarged view of which is shown at A, B, C, &c., Fig. 1,631. Of course, the spouts can be, and are made to any design. (See N, P, R, Fig. 1,636; P, Q, Fig. 1,528; Figs. 1,649, 1,650, 1,655, 1,658, 1,664, &c.) They are also made for passing through the side of the bath, as at R, Fig. 1,632. These fittings are shown at A, B, C, D, Fig. 1,061, which latter will, when fixed in the bottom, also answer for the outlet pipe. The inlets to the baths are often simple cocks or valves fixed as shown at V, Fig. 1,630, as shown at 42, 44, and 45, Fig. 340, and also as shown at my lavatory basin work, Figs. 1,506 and 1,528. Fig. 1,632 illustrates the method of fitting up a bath with the round way ground-in cocks. These cocks when well made with gun-metal will stand under a middling pressure, say from 10ft. to 20ft., as well as anything we can get, and they are a class of cock which allows the free passage of the water through them. We often find it necessary to fix such cocks as those having a gland to keep them watertight round the spindle of the key, and they are made with unions, as shown at B, F, Fig. 998. Sometimes it is by the water companies stipulated that screw-down cocks are to be used, such as shown at the globular valve, Fig. 1,633, also at Figs. 1,634, &c. This Fig. 1,633 is known as the globular pattern, and is nothing more than the Rotherham pattern with ground-in valve, with a rounded body or shell (for section see Fig. 1,677). Of course, when such cocks are used as shown at F, M, Fig. 1,634, the spindle must be fixed to work with socketed keys as usual, and at the ordinary place at the foot of the bath, as at C, H, B.

In this Fig. 1,634 it may be seen that the hot-water pipe, Q, R, S, is taken to the top part of the bath and connected therewith with fittings, as before, and as spoken of at Fig. 1,632. The cold-water pipe, X, Fig. 1,634, may also be branched into this pipe, or taken in on the other side, as shown at E, or otherwise over the top. You will observe that the head of this bath has a square head. This also shows the safe, which all baths should have.

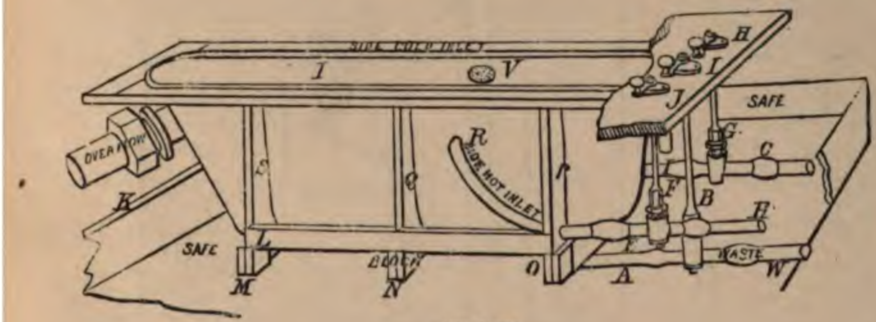


FIG. 1,632.

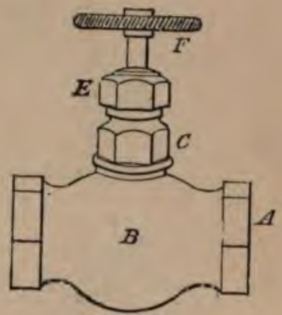


FIG. 1,633.

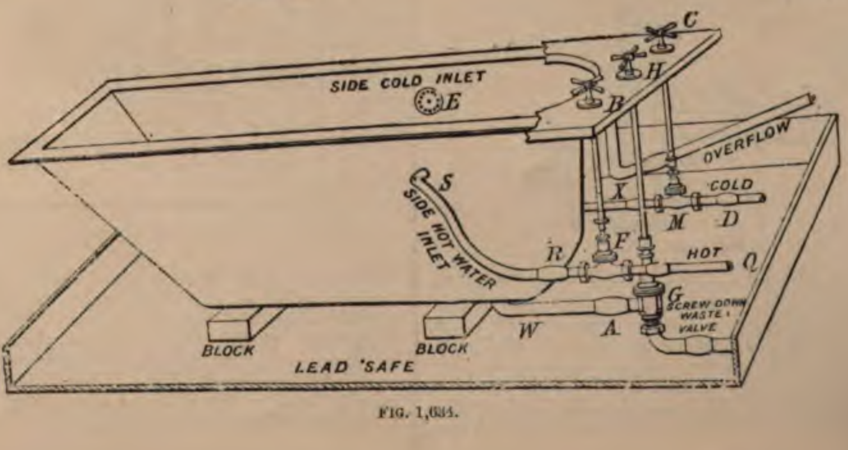


FIG. 1,634.

In Fig. 1,635, at H, may be seen the pipes entering below the water level, which, according to some water companies'

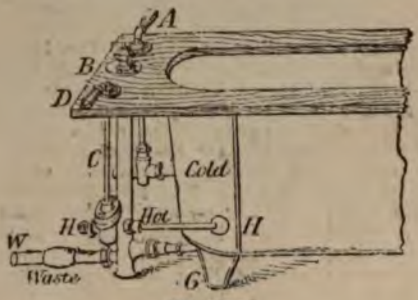


FIG. 1,635.

rules, is illegal. The cocks here shown are of the gland cock pattern, having plain levers for opening.

Bath Standing Waste Pipes.

These are illustrated at Figs. 1,528 and 1,636, and at times are made with cone or other shaped valves and seatings, with standing waste. L, S, Fig. 1,636, is the standard body pipe or shell wherein the standing waste

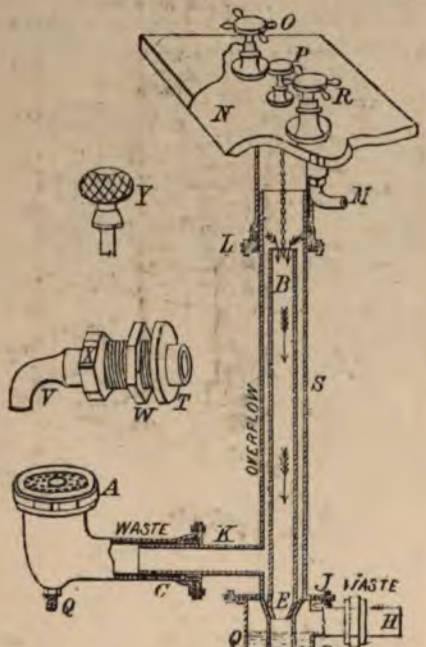


FIG. 1,636.

B, E, works. A, the grating, which may be connected to the bath by means of a bolt and nut, Q. The head of this bolt is made to press upon the grating, and the other screwed end made to pass through the elbow or bend part, as shown, and screwed up with a nut, as shown at Q.

When bedding this elbow to the bottom of the bath, take care to have some good stiff red and white lead putty; well paint round the work first, and, when required, use some canvas, or a piece of old sack-cloth, &c., for the purpose of making the joint sound. In some cases a rubber or leather washer may be used, which, of course, must be left to the judgment of the plumber.

B, is the overflow and standing waste pipe, which can be provided with a rubber valve as at E, the seating of which should be of lead, as the rubber, if allowed to stand any length of time, sticks firmly to iron or brass.

Baths fitted with Simple Shower Bath for rinsing the Soap, &c., off when coming out of the Bath.

(NOT GENERALLY USED.)

For these refer to Fig. 1,637. A, is the shower bath, which is simply a round copper or other cistern about 18in. round, and 8in. deep, having a copper perforated bottom. This cistern is generally fitted with a ball valve, and with a large valve, Fig. 1,638, in the bottom, which bottom is, of course, *above* the perforated or second bottom. The shower bath cistern, Fig. 1,639, is generally supported by iron rods

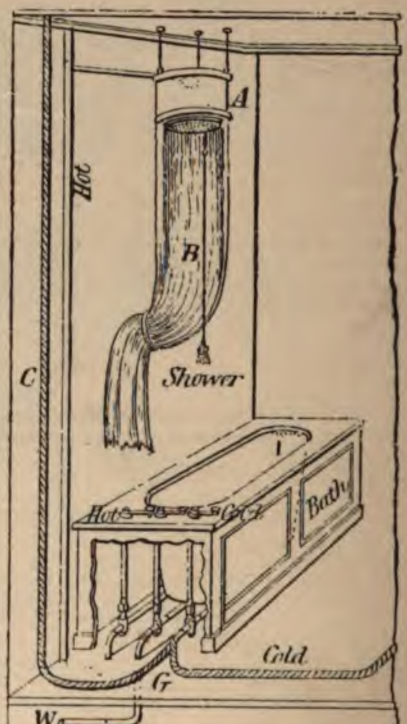


FIG. 1,637.

with lugs, I, J, to the ceiling, and round its outer edge near the bottom, as at K, is fixed an iron or other metal hoop, for the purpose of hooking on the curtain or sheet B, C, Fig. 1,637, which when not in use should be hooked up, as shown at C, but in such a manner that it will not drip upon the woodwork of the bath. Of course, when the hood is fitted to the bath, as at Z, Fig. 1,630, then the sheet or curtain is not required.

The shower bath and fittings are shown at Figs. 1,638, 1,639, and 1,640. A, is the shower bath cistern; H, a lever; L, the wire connected to the valve; K, the wire from the handle or pull. This pull may be as at K, or worked by a side pull, and cranks, &c., as desired. M, B, Q, Fig. 1,638, is the large valve, generally from 2½in. to 3in. in diameter, which is soldered into the bottom of the cistern

FIG. 1,638.

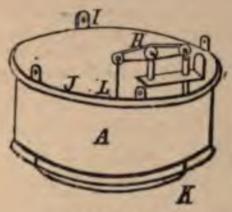


FIG. 1,639.

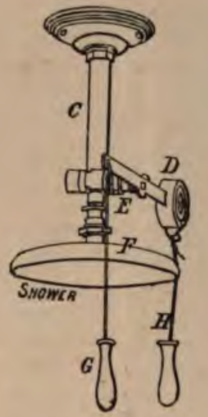


FIG. 1,640

and worked by the wire L. Below the large valve is, as before-mentioned, a perforated bottom to part the water in a similar manner as the rose of a watering can, and as shown at 4, Fig. 1,630. Fig. 1,640 illustrates the shower bath with a kind of stool-cock lever, and a stopcock arrangement, or worked with a lever and weight, and with a flange to fix to the pipe in the ceiling, which is too simple to require further explanation.

Needle, Shower, Douche, and also Spray Baths.

The bath illustrated at Fig. 1,641 is nothing more than one, two, or three fixed roses, as at A, K, R, which are in shape similar to a gardener's watering pot rose. These roses are shown at 35 and 36, and are made to screw on to the ordinary stopcock, as shown at D, or to pipes leading from stopcocks or valves, as at B, A. Sometimes all round the inner circle of the copper hoops 1, 2, 3, 4, &c., is a quantity of holes to allow the water to play out at every part. These holes should be made to a size suitable to allow the water to spout out and across in such a manner that the whole will come out with force, and cross each other so as to have the appearance of so much steam, as at 5 (Figs. 1,630, 1,645, and 1,646). Or, instead of copper pipes, lead pipes have been used and stand fairly well, or the spray may be formed by soldering half pipes, as at L, M, N, O, P, Fig. 1,630, on to a piece of sheet copper, the inside of which may be perforated as desired. Or, instead of these half pipes (which resemble astragals), two pieces of metal may be soldered together to form a water reservoir, which may be, on the inner surface, perforated, as shown at the spray (Fig. 1,645), and, in fact, many other ways.

In order to get this properly to work you must have the pipes and *valves* large, and a good fall and *force* of water. On the top of each pipe, as at S, T, W, 16, 17, 18, 20, 21, 22, Fig. 1,641, should be fixed a straight *full* way regulating stopcock, and the pipes branched into the large one. The main pipe 15 should be governed by one large, say 2in., valve, such as illustrated at Figs. 514 and 523, also at G, Fig, 1,630, and at D, E, Fig. 1,640.

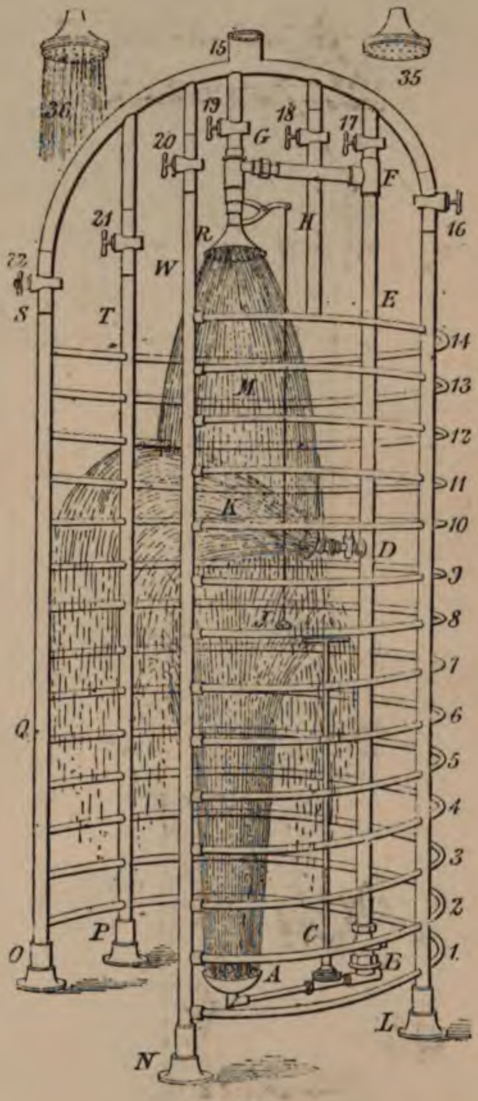


FIG. 1,641.

Fig. 1,642 illustrates a shower and spray bath of the simplest construction, there being but one pipe required to work it. It should be remembered that these baths require a large quantity of water and a strong pressure to make them effectual, so that when you require to make such, first calculate the number of holes which you have in the rose and add them together, and one and a half this will give you the size of pipe required; but the f pressure will make a great difference in the workin fall of water should not be less than 8ft. or 10ft. abo top rose, without sharp bends or cocks having er ways or sharp turnings at the valve seatings.

In Fig. 1,635, at H, may be seen the pipes entering below the water level, which, according to some water companies'

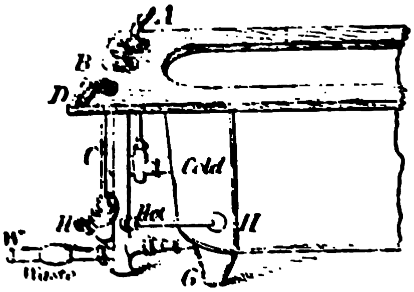


FIG. 1,635.

rules, is illegal. The cocks here shown are of the gland cock pattern, having plain levers for opening.

Bath Standing Waste Pipes.

These are illustrated at Figs. 1,528 and 1,636, and at times are made with cone or other shaped valves and seatings, with standing waste. L. S. Fig. 1,636, is the standard body pipe or shell wherein the standing waste

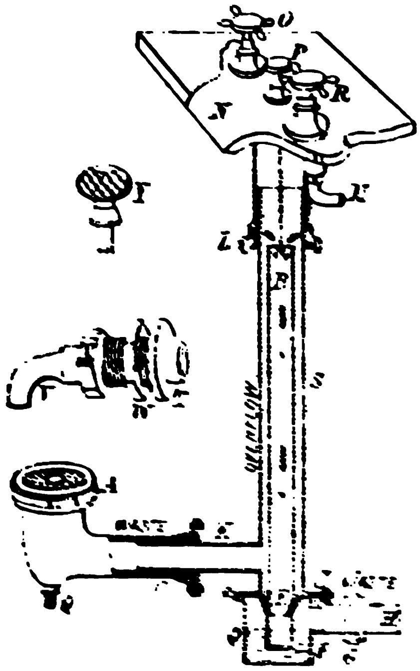


FIG. 1,636.

R. R. works. A. the grating which may be connected to the bath by means of a bolt and nut, Q. The head of this bolt is made to press upon the grating, and the other screwed end made to pass through the elbow or bend part, as shown, and screwed up with a nut, as shown at Q.

When jointing this elbow to the bottom of the bath, take care to have some good stiff red and white lead putty well put round the work first, and when required use some canvas, or a piece of old sack-cloth, &c., for th purpose of making the joint sound. In some cases a rubb or leather washer may be used, which, of course, must b left to the judgment of the plumber.

B, is the overflow and standing waste pipe, which can i provided with a rubber valve as at E, the seating of whi should be of lead, as the rubber, if allowed to stand a length of time, sticks firmly to iron or brass.

Baths fitted with Simple Shower Bath for rinsin the Soap, &c., off when coming out of the Bath.

NOT GENERALLY USED.

For these refer to Fig. 1,637. A. is the shower ba which is simply a round copper or other cistern about [illegible] round, and 8in. deep, having a copper perforated botto This cistern is generally fitted with a ball valve, and wit large valve, Fig. 1,638, in the bottom, which bottom is, course, above the perforated or second bottom. The sh bath cistern, Fig. 1,639, is generally supported by iron [illegible]

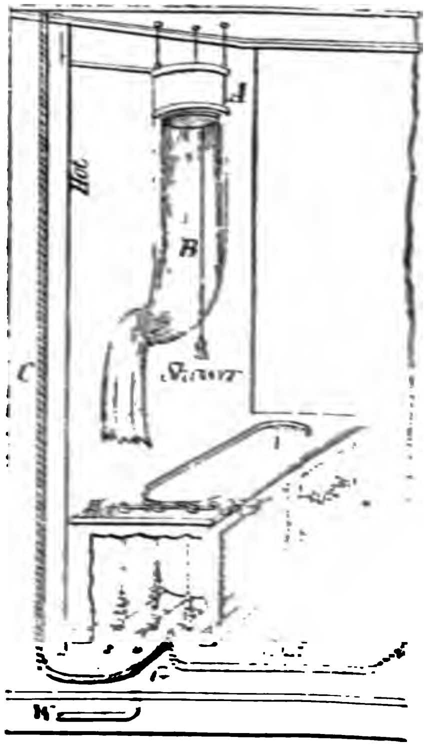


FIG. 1,637.

[illegible]

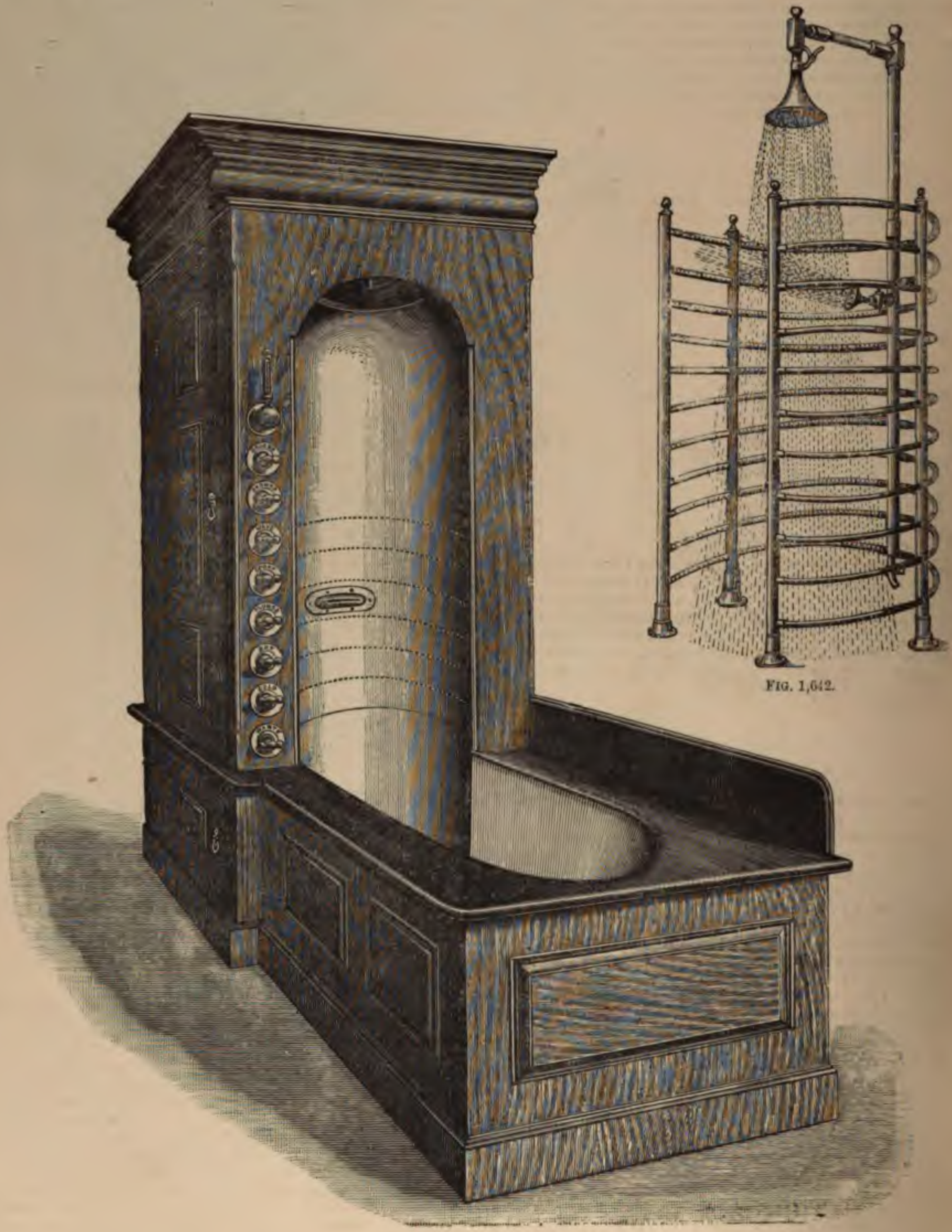


FIG. 1,642.

FIG. 1,643.

Fig. 1,643 is a system whereby the water supply is somewhat modified, so as to bring the water into a kind of mixing chamber, as shown at Fig. 1,644. Here the valve inlets are brough. into a kind of box, which box leads or communicates with the desired supply, viz., douche, shower, wave, spray, plunge, with the two valves below hot or cold, or in lieu of these valves going into a mixing box they are sometimes arranged as shown at Figs. 1,644A and 1,644B.

To the mixing box, Fig. 1,644, a thermometer, shown on the right of the figure, may be attached, as shown, above the valves in Fig. 1,643, which is fixed in such a manner that when the hot and cold valves are open, the water passes through the box, round the bulb of the thermometer and out of the standing waste of the bath. It will be seen that in Figs. 1,644 and 1,644A, that the top and stuffing box may be easily taken off for repairs.

It can also be seen that by opening the hot and cold water that this water can be conveyed to the plunge, spray, wave, shower, or douche, or at two or more outlets at once. Of course, the valve seatings are some for inlets and some for outlets; this being the case the jumper part of the valve should be attached in the usual loose manner, for valves opening against the stream, and with a washer encased, as described and illustrated at Fig. 532.

This distributor, Figs. 1,643 and 1,644, is Messrs. Emanuel and Sons' arrangement, and an excellent one it is, and the cabinet work is as good as anything I have seen for stability.

Instead of having a separate cock for each outlet, viz., for douche, spray, needle, or other supply, it can be done with two cocks only, one off the hot, and the other off the cold, communicating with a sliding or other ported distributor, whose parts may be branched to the required outlets, as shown at Figs. 1,647 and 1,648.

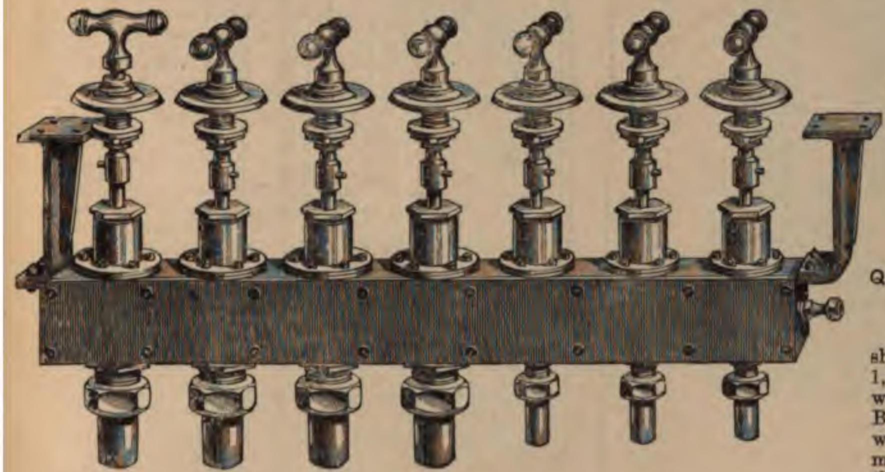


FIG. 1,644.

FIG. 1,644A.

FIG. 1,644B.

Quick Wastes for Baths or Wash-hand Basins.

Although I have described and shown the standing wastes, Figs. 1,636, &c., at considerable length, which wastes have overflows as at B, Fig. 1,636, in juxtaposition with the waste pipe H, and is much practised, it is not by far the best known plan, because in these wastes the drag or weight of water in the waste pipe H, is interfered with, by the air entering at B, and will be known by the disagreeable gurgling noise it makes. The best way is to use a valve for the outlet, such as is shown at Fig. 1,537A, making M, the inlet, so that the air cannot get into the waste pipe. For my part, where practicable, I always use a 1in. or 1¼in. easy turning round way ground-in gun-metal gland cock with unions and key for my wastes, with a tray below, or, if this be too expensive, I prefer a simple plug and waste with chain, always keeping the overflow quite separate from the waste pipe.

If Fig. 1,636 must be used, see that the gratings and the waste pipe A,K, be at least three or four times larger in bore than the size of the outlet waste pipe H, or, in other words, if H, be 1in., A,K, should be 2½in. to 3in. bore, to ensure silence in a quick waste, whose length, we will say, is 20 vertical feet.

Casing up the Bath.

This illustration, Fig. 1,645, explains the method of fitting the wood work to the needle and shower bath. It also illustrates one method of fixing the pulls, 1, 2, 3, 4, &c., which may turn simple screw-down cocks, or, as in this case, be made to work necessary cranks or chains over pulley wheels, &c., which in their turn work such valves as shown at Figs. 527, 529, 541, 542, and also to work screw-down cocks such as are shown at Figs. 518, &c., which may be fixed at the back or head of the bath. It also illustrates the examination doors, and the whole thing in action. Fig, 1,646 illustrates the bath with the examination doors open.

Fig. 1,646

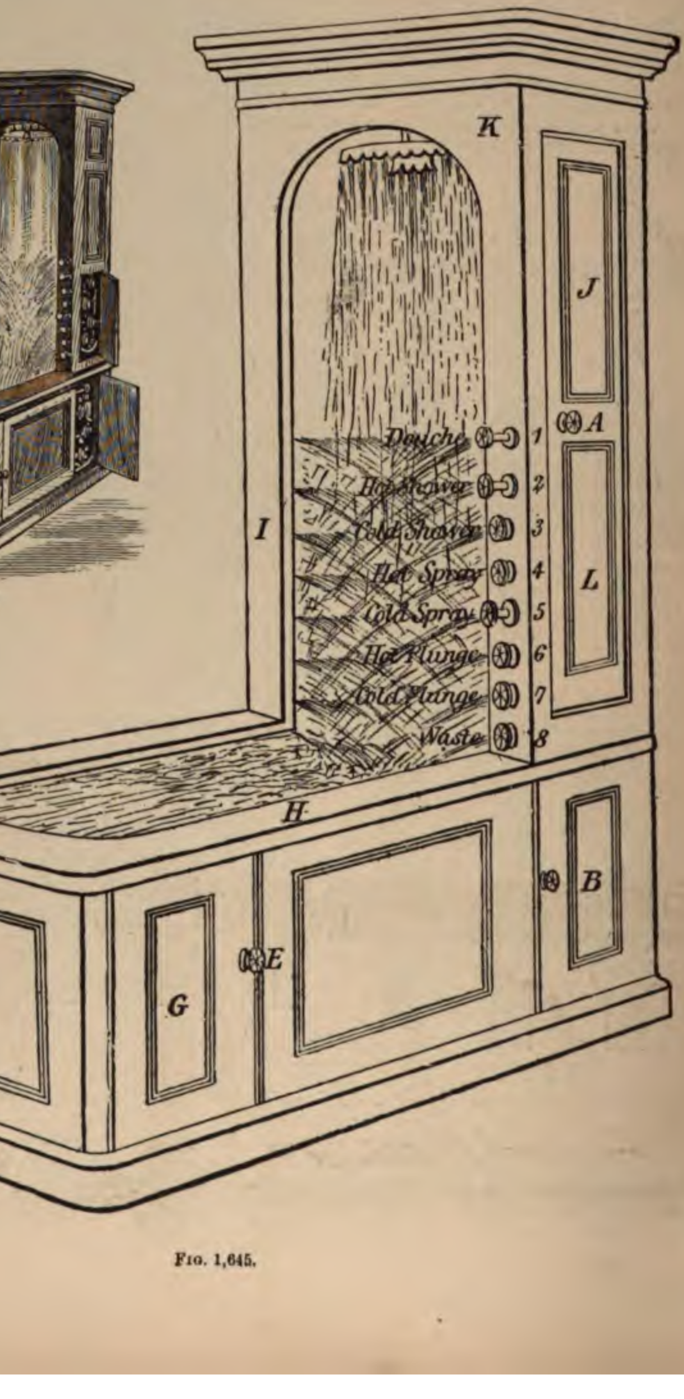


Fig. 1,645.

Bath Distributors.

(*Figs.* 1,647 *and* 1,648 *explained.*)

It may be seen that, instead of having eight different valves and knobs, two only are required—one for the hot and one for the cold—with their outlets communicating with the before-mentioned distributor. The internal parts of this distributor are as follows :—H, is the brass or gun-metal outer case, about 1in. broad and from 8in. to 6in. in diameter, having at the back as many outlets as are required

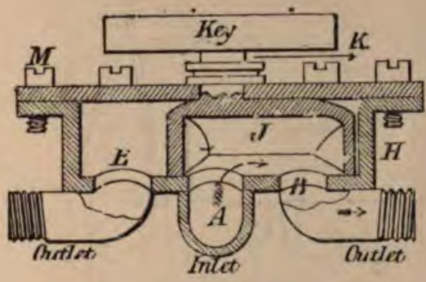


Fig. 1,647.

for the different sprays to be used, and as shown at B, C, D, E, F, G. A, is the inlet, which is covered with a directing movable slide, J, having sides and ends (see J, section), and is free to move in a circular direction for the purpose of guiding the water from the inlet A, to B, see also A, B, Fig. 1,648. J, Fig. 1,647, is the section of this circular moving slide, showing a water passage or a clear communication between A, and B. This guide is moved in any direction by the KEY or crutch, on the spindle of which is fixed a pointer, K, to indicate which port-hole is open, and now indicates the port-hole open, which may lead to the communicating pipe, leading to the needle or douche bath. It will readily be seen that on turning the key either way that a water-way may be established between the inlet port, A, and any of the other ports. For argument's sake, say that you turn the pointer round to M, this will establish a water passage between A and the port E, and so on. Of course, the outlets of this distributor should be screwed or otherwise made suitable

Fig. 1,648.

for connecting the ends of the pipes to, according to circumstances.

Bath Supply (at the Foot).

Sometimes the supply to baths will answer best if taken over the foot, as shown at Figs. 1,649 and 1,650. This is designed to meet the requirements of the Metropolitan Water Act of 1871, and is supplied in a similar manner to that shown at Figs. 1,504, 1,542, 1,545, &c.

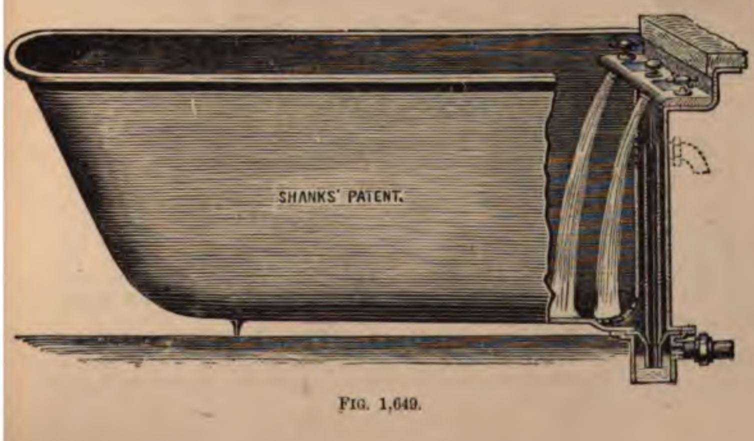


Fig. 1,649.

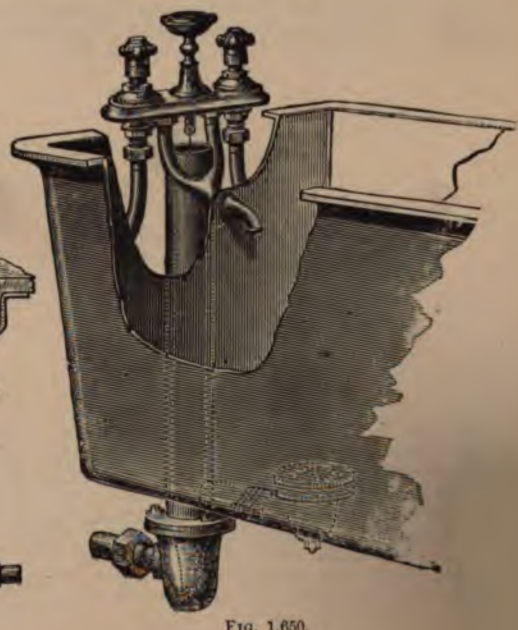


Fig. 1,650.

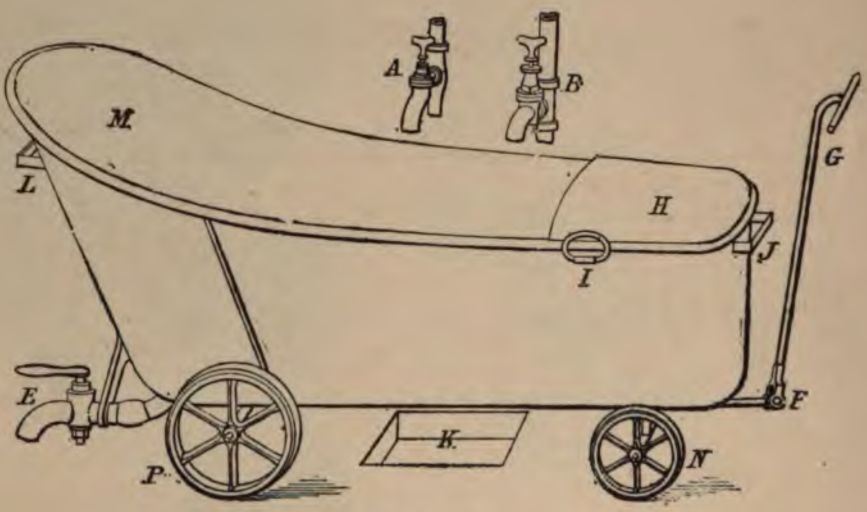


FIG 1,651

Hospital Portable Bath on Wheels.

These baths are great luxuries to the patients in hospitals, &c., and every architect should see that proper provisions are made for filling and emptying them. The best method is to fix two cocks, as at A, B, Fig. 1,651, to run water over the side or head of the bath, having short lengths of rubber hose slipped over the nozzles of the cocks, or by the use of a proper hose union, as fixed at R, on the diaphragm cock, Figs. 1,652 or 1,653, or by the use of a slip con-

FIG. 1,652.

nection, E, F, G, Fig. 1,653. This bath also requires some provision to be made for emptying it. This is generally made as shown at K, Fig. 1,651. It is a sunk well, lined with lead, having a 2in. or 3in. lead waste pipe, with a large grating, capable of allowing the waste water to run away as fast *as the bath delivers it.*

The hole in the bottom of the bath is sometimes governed by a simple plug having a short length of pipe, and at times having a short piece of indiarubber pipe slipped over its end to guide the water into the sunk well without splashing, or this pipe may be governed by a cock, as at E, P, which is much the best, for many reasons, if the attendants are careful and if the cock is far enough under the bath. At the Hospital for Incurables, Putney Heath (and for which building I hold a certificate for excellence in plumbing, granted by Mr. Griffiths, the architect, and Messrs. Sims & Martin, the builders), we, many years ago, made sinks for backing the bath up to,

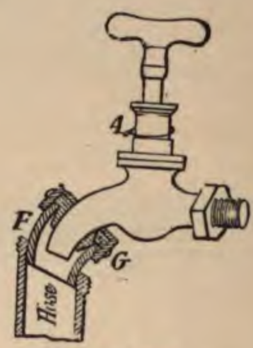


FIG. 1,653.

and allowed the same to empty through the cock, E. whilst the filling cocks, A, B, were fixed so as to run over the head part of the bath, which prevented them being knocked by the head of the bath.

These baths should run on iron wheels, having grooves to receive indiarubber tyres, and should be made with a splash apron, H, and with a hinged pull or handle, F, G, Fig. 1,651.

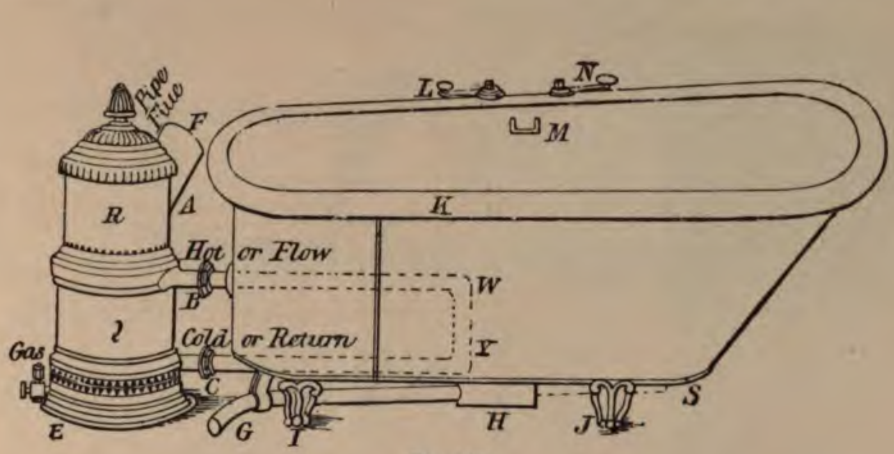


FIG. 1,654.

Gas Baths.

These baths are very numerous: some are very good, and others very bad. The principal points to look out for in these baths are, first, secure proper atmospheric burners, which will consume all the gas sent through them without making a stink. There should always be a pipe flue fixed, to carry away any unconsumed gas into the open air, or the boiler may be fixed outside the bath room or in the open air. The boiler should be large and of the best possible shape. It should heat the bath in about fifteen minutes. This can be done with the bath illustrated at Fig. 1,654. Q, is the boiler; E, the swinging now enclosed burner; A, the flue; B, the flow; and C, the return pipe, which latter should be taken to the head of the bath at S, in order to get the coldest water; H, is the well, and L, N, the water supply and waste handles. R, towel warmer, having a lid on top. It may at a glance be seen that this bath has a large stiffening bead (K) round the top, and it is generally painted outside to save the expense of casing. In fact, as a rule, gas baths are purchased because of their low first cost and for transportation.

The gas bath may be made without a separate boiler by arranging the gas jets to play upon the bottom of the bath, as at E, &c., Fig. 1,655. Sometimes the hot water, as well as the cold water supply, is laid on to a gas bath, as shown at H, J, K, Fig. 1,655, the gas being a secondary provision, when the kitchener is not wanted to work. This is very handy when a gentleman's family are out of town, and a warm bath wanted on, only, a casual visit.

Also see dome shaped boilers, Fig. 1,581. Also see Fig. 1,579 for occasional bathing. For heating by gas, also see Figs. 760, 761, and 762, and Steam Kettles.

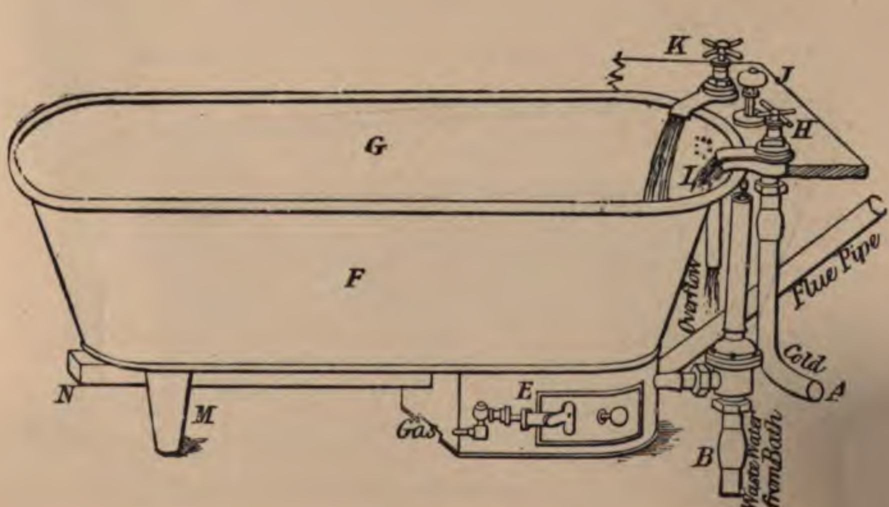


FIG. 1,655.

FIG. 1,657:

Fig. 1,656 is a simple gas bath and towel warmer at the foot, through which the waste heat passes without getting

FIG. 1,656.

at the towels, and thence away or condensed as most convenient. This flue, from the burner, passes under the bottom of the bath, which assists to economise the heat.

The Lightning Bath Heater or Geyser.

Fig. 1,657 is Ewart's patent, and an excellent water heater it is, and will be readily understood when read in connection with Figs. 760, 761, and 762, Vol. I.

Fig. 1,658 illustrates the Fig. 1,657, fixed at the foot of the naked bath, and as turned out ready for the plumber to make his connections.

Fig. 1,659 is the same lightning geyser heater as fixed on an ordinary cased-in bath, and is very useful when the hot water from the range falls short. These geysers are made in copper and do not at all disfigure the bath room. Or if this should be an eyesore, it can be placed in any odd out-of-the-way place, and the pipe brought to the bath as desired.

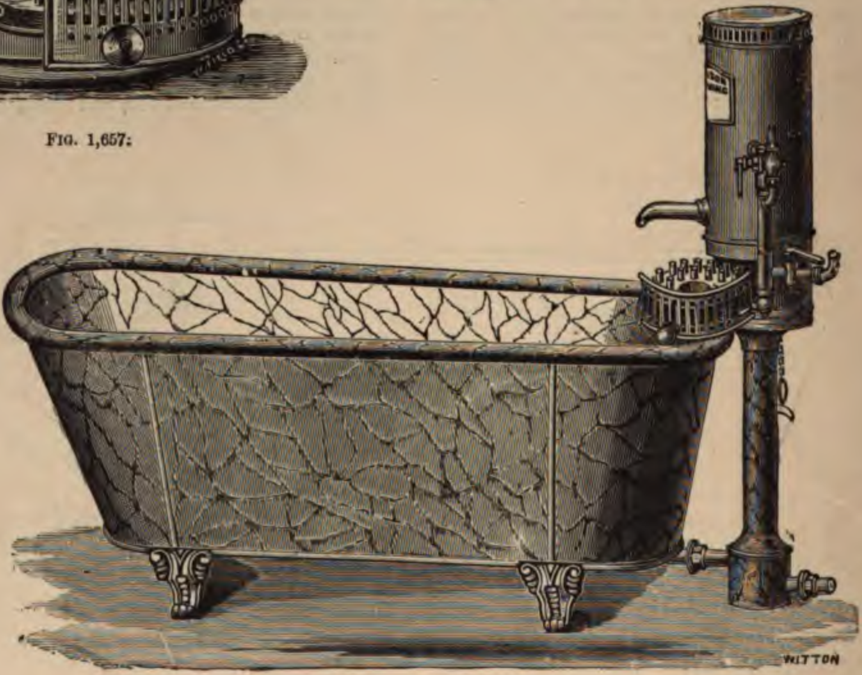


FIG. 1,658.

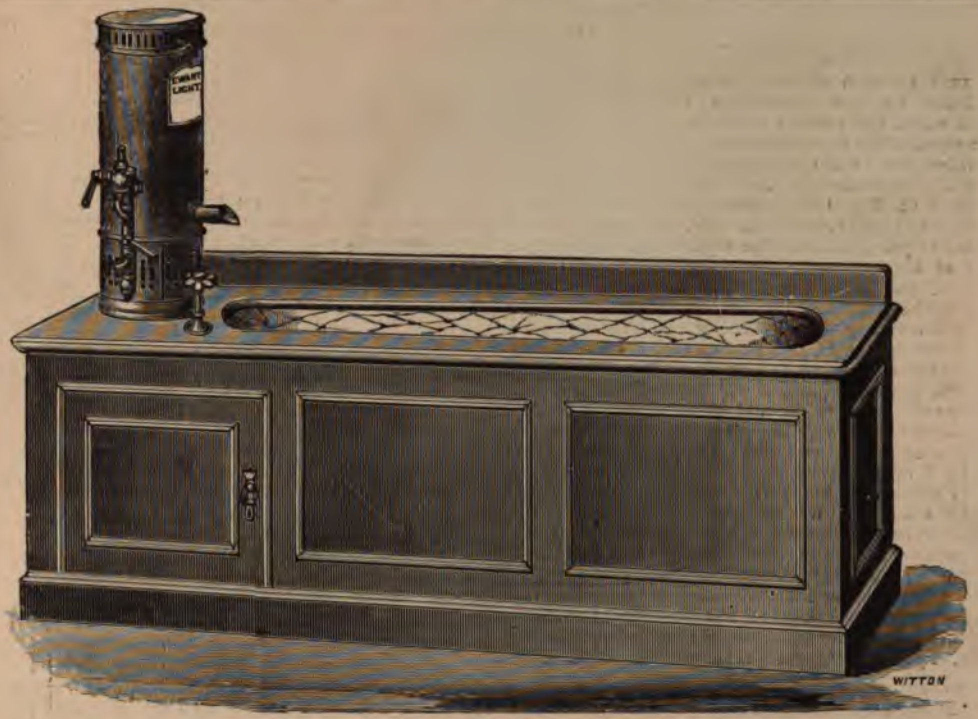


FIG. 1,659.

Turkish or Hot Air Baths.

This misplaced term should be abolished, as I like to call a spade a spade. The Romans called their baths "themæ," from the Greek "thermos" (heat). It is said that these sweating chambers are of great antiquity, possibly used in the Phœnician cities of Tyre and Sidon. A Turkish bath is nothing more nor less than having a good hot bath, then placing yourself in a very hot-air sweating chamber, so that the pores of the skin may be well expanded, to allow free perspiration all over the body, after which, and while in this condition, you get someone to give you a good rubbing and lathering with soap and hot water, until you can stand it no longer. You then get a good swill off with hot water from a garden pot and rose, or otherwise, and finish off with cold water to close the pores of the skin, and an hour or two's lazy lounge to finish up with. You should be particularly careful to use discretion when indulging in such too-much-talked-of luxuries, which, for my part, I think little of. You can use your discretion as to how you form your sweating chamber, which should be well ventilated with a moist atmosphere.

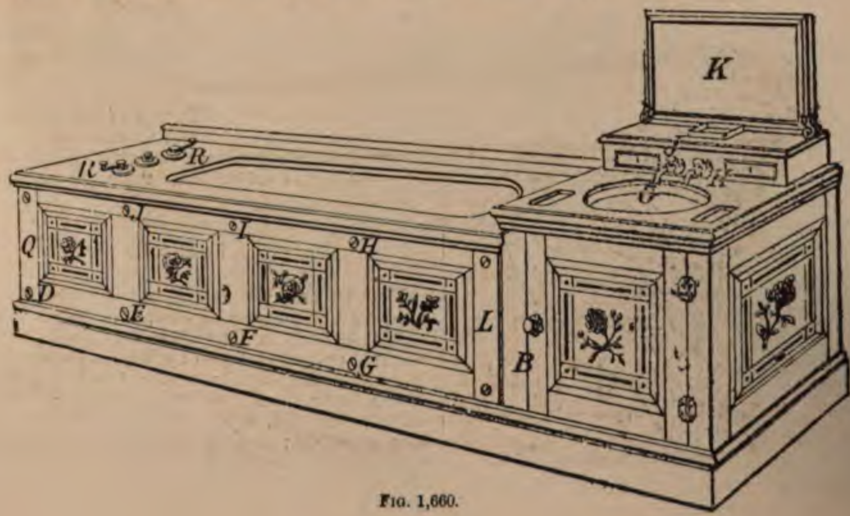


FIG. 1,660.

Casing for Baths (*continued*).

I, as well as most other plumbers, have felt great inconvenience by the injudicious manner in which carpenters make the casings for baths. They generally make the examination doorway much too small to get at the cocks. When left to the carpenter, it is a very common thing for him to make the door with one of the small panels, as at Q, Fig. 1,660. Such panels rarely exceed 10in. square, and when such is the case, it is impossible for the plumber to get at his work for repairs, &c., and is often the cause of his pulling the lot to pieces, to the great annoyance of the householder. The proper thing to do with, say, the bath before our notice, is to make the door at the end, so that it may open in front of the lavatory basin. If a door is fitted as at B, and this end of the bath made the foot (the reverse to what is here shown) for the purpose of fitting the cock handles, the plumber will have a fair chance to examine the work, and to do necessary repairs without pulling the lot to pieces, and often at half or quarter the cost than when otherwise arranged. Here I may state that the head of the bath should be fixed opposite the window, in order that the person using it may get the advantage of the light. When a door cannot be made, then screw the front on to a frame in such a manner that it can be easily unscrewed, as at D, E, F, G, H, I, &c., and taken down, but notice when such screws are used, take care that brass eyelets are used, and brass screws, so that they may be taken out without damaging the woodwork, and see that, if the front is painted, that the painter does not fill them up with putty or "gorm" them up with paint.

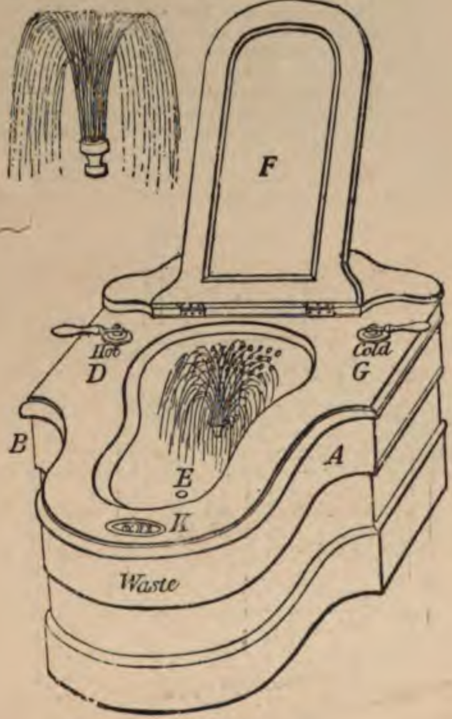


Fig. 1,661.

Bidets.

These are simply a small kind of bath, whereupon you can sit on the parts marked D, G, Fig. 1,661. The hot and cold water is branched into one pipe, and enters as shown at the spray E, when it will flow away; or it may be allowed to fill, according as is required. The temperature of the water may also be regulated by the handles D, G, to suit.

Fig. 1,662 illustrates a bidet having the top narrower, that you may straddle and sit at A, B. The valves may be worked at the point E, F, or by the pedals C, D, and also on

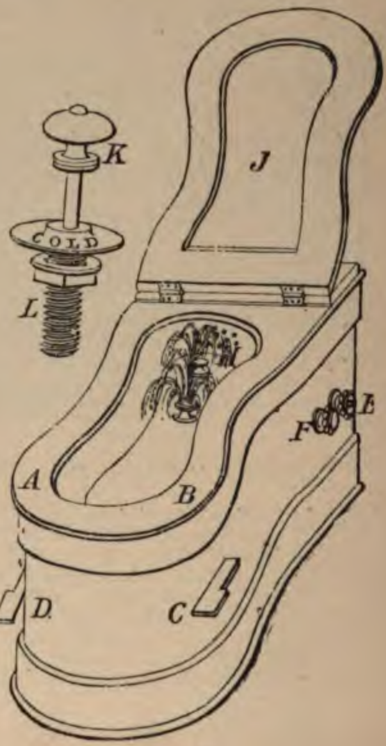


Fig. 1,662.

the top. Of course, with any of these bidets any of the before-mentioned cocks and valves may be used. I may say that there are a large variety of bidets in the market, but nothing is better than these shown. Also see Fig. 1,525.

Public Baths.

Now we are upon the subject of baths, and have shown almost every conceivable kind, excepting a public bath.

Fig. 1,663 is an illustration of half a dozen public baths, as fitted up and arranged by Messrs. Bailey, and Fig. 1,664 is an indexed distributor for the hot and cold supply. These baths should be fitted with 1in. to 1¼in. supply valves, with 2in. waste, in order that they may fill and empty quickly; and the indicator fixed in the corridor or passage to be under the control of the attendant only. There are many ways to arrange the waste pipe, valve, pulls, or levers.

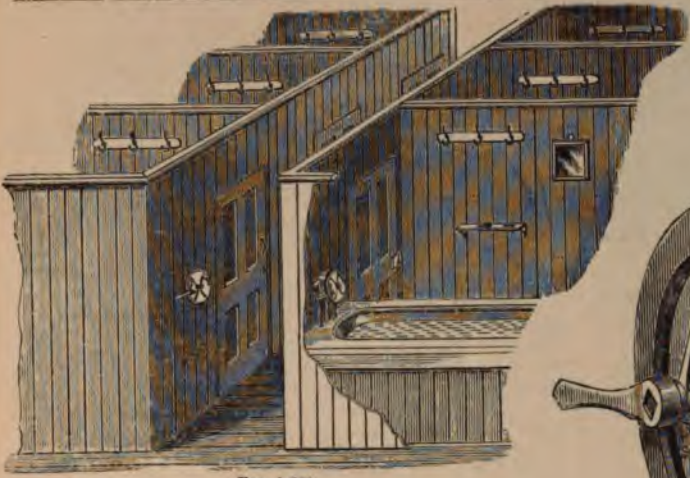


FIG. 1,663.

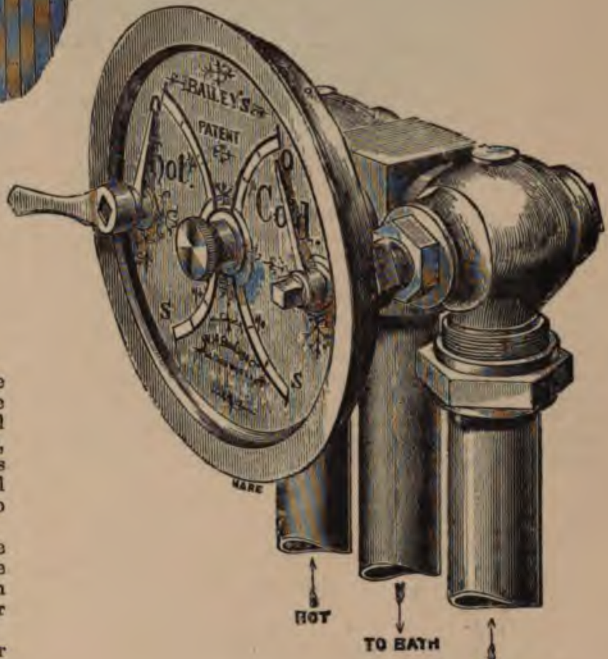


FIG. 1,664.

Swimming Bath.

Fig. 1,665 illustrates a swimming bath made upon the most improved principles. It can be seen at F, that the fresh water enters at the cascade, a little above the level of the water in the bath, which assists to aerate the water, and has the advantage of being seen when on. At A, is the overflow, this, being a long kind of trough, catches all the light floating substances and conveys them at once to the drain.

In order to keep it at a certain temperature, pipes are employed at any convenient place, or hot water can be pumped, as shown, by a pulsometer from a hot well or from the bath into a boiler, or it may be worked in many other ways which is shown in this hot water work.

If the pulsometer is used for water raising, or for aerating purposes, its steam required for the working will often heat the water to the required temperature.

Of course any injector or other kind of pump can be used, or the water laid on from the street main. A ready means of emptying or other preventative should be looked after against drowning, &c.

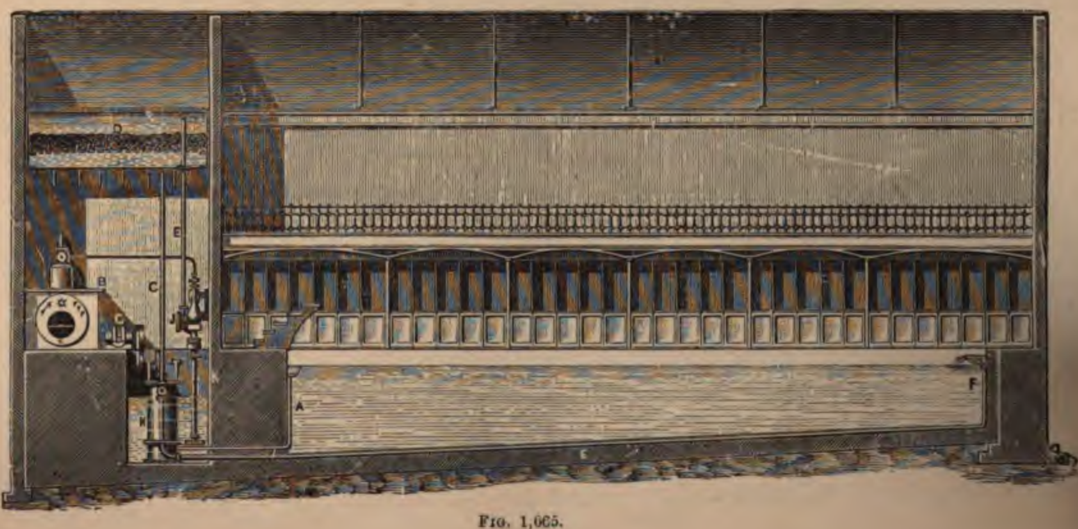


FIG. 1,665.

REPAIRS, COCKS AND VALVES.

Hot Water Cocks, Valves, and Brass Work.

Having gone through the principal parts of our hot water fittings for sanitary purposes, nothing now remains but to examine and fix the cocks and other minor fittings, then we may proceed with the warming branch of the work.

We have seen sufficient of the costly class of water supply to baths; we will now examine a few cocks and valves of an inexpensive character which you will be certain to find during repairs, &c.

Down-right Bath Cock.

This very useful cock is shown at Fig. 1,666. It is, as can be seen, a ground-in, old-fashioned cock, and I daresay that some of my fancy brethren, who have never seen any work but what has been practised in one or two firms and trotting about the country where they have happened, more by luck and gas than sound practical plumbing, to hold their own, will, as it is well known they have done, especially with the O trap, instead of rectifying the evils of their fellow-workmen, who were responsible for their barn shape, condemn good, old useful servants wholesale through the plumbing trade, and I must say that during this last sanitary bubble I have, unfortunately, found many men who one would not credit to have such extremely biased ways. I said ideas, but I can prove that they are not

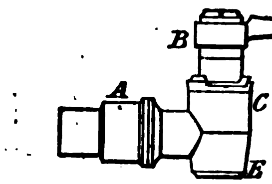


FIG. 1,666.

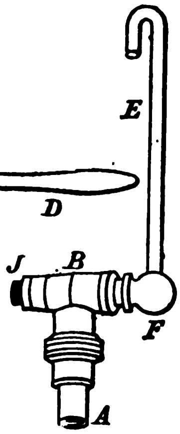


FIG. 1,667.

their ideas, for many have actually told me: "Oh, what's the odds, it makes work," and it is through such infamy that the plumber has lost his individuality in the trade. Look what the plumbers have brought upon themselves through such greediness. The customers were driven to their wits' ends to know how to cope with these extravagances, and, instead of sticking to their old firms, were pressed to seek redress in other quarters, by going in for something cheaper, and in came the ironmonger, tinkers, &c., and in turn goes in for cheaper material. There is a demand and a market for ready-made goods; and, the plumber, as was the case when I was a boy, instead of working three or four days a week in the shop now does not get one. To illustrate to you plumbers of to-day clearly what you have done within the last few years, let me remind you of a few little things we used to do. First, we cast large quantities of sheet lead especially for cathedral and church work, which cast lead holds its own to this day, though, because you have nearly lost the secret of working it, you condemn it—its a fact. We also used to be the recognised people to fix a cock, with the bossing irons, but I fancy I hear my fellow workman say, "Oh, but look at the improvement, having a screw boss"—perhaps so, for the ironmongers. Next, we will take the soil pipe; this was something to fall back upon, but to-day how many plumbers in London can be found capable of properly *drawing* a length of soil pipe from a sheet of lead fit to be seen and in reasonable time? Next comes the service boxes and traps, but where are these made to-day; even the making of the bends is driven out of the shop. Why? Because in a great measure the faddist plumber has his own ideas, and don't care how or in what way he injures those that follow him. Everything new, and with plenty of gas, must be best, 99 per cent. of which prove to be white elephants, which make the work twenty times more expensive than it should be. And mark you this, the real plumber does not profit by it. But who does? Why, the sanitary quack, who is idolised by the duffing plumber.

Now we will resume our hot water cock work of the ground-in character. For supplying water into the foot-part of the bath it is best knighted as at C, E being the outlet. The spanners should be made with a non-heat conducting material, viz., made of wood, as shown at Fig. 1,670.

Swan-necked Lever Cock.

The plug of this cock, Fig. 1,667, is in shape similar to that shown at Fig. 1,666, excepting that the outlet is at the large end, F, and a bottoming nut and washer used, as at J. It is used in places where the snout of the cock is objected to being fixed over the top of the bath. (It is also used for butler's pantry sinks.) It will readily be seen, that with such an arrangement the cock may be fixed a foot or two away, and that by pulling down the swan-neck, E, the plug of the cock will revolve, and water run through this swan-neck and into the bath. Such cocks are also used for lavatory basins, butler's pantry and housemaids' sinks, &c. For hot water provide a wood handle at E.

Self-tightening Plug Cocks.

In this cock, Fig. 1,668, as may be seen, the plug is self-tightening. The action is as follows:—The boss, A, unscrews at B, and the plug at this point may be taken out, that is after the bottoming nut, E, has been taken off. The large end of the key is hollow, the small end solid (just the reverse to the plug of the down-right cock). There is a water-way on one side of this hollow key, and it being fitted to come opposite this port hole, or way of the shell at J, it then follows that there must be a passage through the cock. Now turn off the key, so that its water-way will be opposite D, this water passage will then be cut off, and the pressure of water will tend to push the key through the shell of the cock, and therefore tend to grind itself in every time it is turned. I may add that if this cock be fitted on pipes under heavy pressures, its plug will be apt to jam, and, also, will soon be worn away. It is a good cock for pressures ranging from 5ft. to 20ft., but if put on a main of say 300ft. it will, by reason of the water driving the plug, go very hard, and necessarily, as before said, soon wear away.

I like the cock very well for ordinary hot-water work—say up to 20ft. ~ I have made this cock with two or more outle rs the purpose of the before-described di

Shell Pattern Hot Water Cocks.

These cocks are illustrated at Fig. 1,669, and when made from E, to B, viz., with short screw, are called HOB cocks, but if made with long screw, from F, B, then they are range or boiler cocks, and are generally made in gun-metal, this being the hardest and best kind of metal for all hot water fittings having frictional parts. Sometimes they are made in brass, but very seldom, more often in pot metal, for a cheap kind of work; the pot metal being softer and easier for the cock maker to finish, especially the grinding-in part.

The barrel or shell of this cock is sometimes made very long and narrow, as shown at A, C. I have made $\frac{3}{4}$in. cocks with only $\frac{3}{8}$in. elongated inlet port-hole, that from C to A, so that the water-way may be elongated in order to ensure the soundness of the plug, and at the same time to get the necessary water-way. Also see Figs. 1,004 and 1,010.

Solid End Cocks.

For very high-pressure work it is a common thing to cast this shell pattern cock with the inlet or boss part, B, Fig. 1,669, quite solid (known as solid end cock), and then to drill a small, say, $\frac{1}{8}$in., hole, or water-way, before the barrel is bored. By doing this the plug of the cock is not so much exposed to the water within the ordinary water-way, and accordingly will be the chance of soundness, and by adopting this method, the water can be drawn without that rush which is always to be observed when drawing water under pressure with the ordinary cocks.

Range, Boiler, and Bib Cock (plain pattern).

This cock, as illustrated at Fig. 1,671, is known as a round way pattern hot water, gun-metal, range, boiler, or bib cock; or, when made with a short screw, as a full way pattern hob cock. The cock is sold without the spanner, Fig. 1,672, unless otherwise ordered.

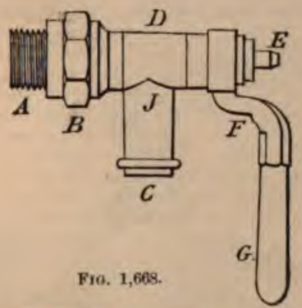


Fig. 1,668.

Fig. 1,669.

Fig. 1,670.

Fig. 1,671.

Fig. 1,672.

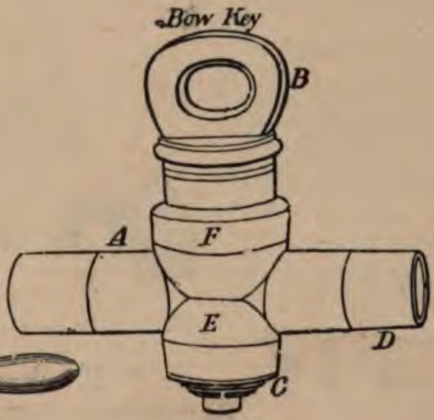


Fig. 1,673.

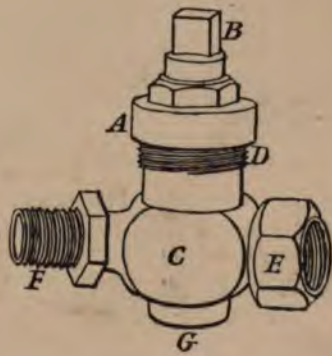


Fig. 1,674.

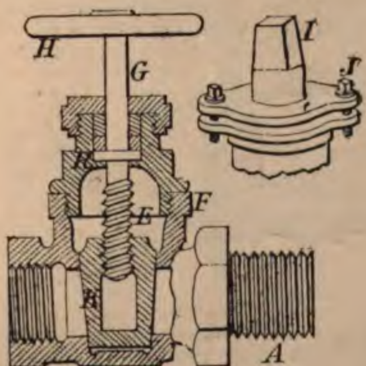


Fig. 1,675.

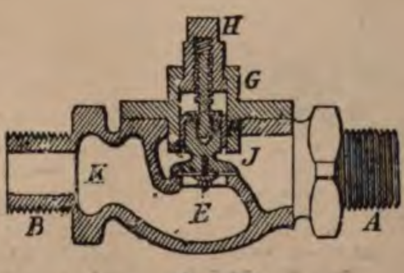


Fig. 1,676

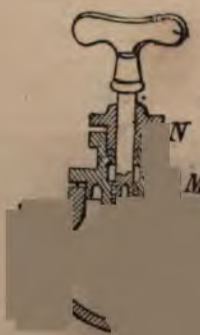


Fig. 1

Hot Water Cock Spanners.

The best kind of spanner is that having ebony, or other hard wood, round the handle as a non-conductor of heat, and as shown at SPANNER, Fig. 1,670. Fig. 1,672 illustrates the ordinary brass spanner. Take notice, a cock is a range or boiler cock when made with a long screw F, Fig. 1,669, and a back-nut G. Also see Figs. 1,009 and 1,010.

Bow Key Round-way Cocks for Cold Supply to Baths.

These cocks are generally used on the best class of work. They are illustrated at Fig. 1,673, and at J, Fig. 1,085: and are well adapted for the cold supply to the hot water tank, and in such places as at C, Fig. 1,572, and at M, Fig. 1,624, instead of the spindle valve and air pipe, as at E, F, Fig. 1,086.

Now we have bath stopcocks under our notice, it will be as well to examine one or two more suitable for the different classes of work. Fig. 1,674 is a screwed gland stopcock. This cock is not so good as the gland cock (Fig. 514), because the cap A, Fig. 1,674, is likely to become unscrewed by the simple turning of the spindle of the plug, especially unless you have a set screw at or about A.

Wedge Stop Valves.

Fig. 1,675 is a valve made after the manner of a sluice valve; K, is the wedge, which is scraped, or otherwise fitted into the shell. The wedge is prevented from revolving upon the screwed spindle by a stop. These valves admit a full way passage for the water, and if well made are very good.

Globular Valves, with Cup Leathers instead of Stuffing Boxes.

This valve is that illustrated at Fig. 1,676, but is only for cold water, it having a cup leather F, in lieu of packing. The valve of this globular cock is also seated as at J, with leather or rubber, to do away with the grinding in. M, N, Q, Fig. 1,677, is the valve with stuffing box, and with a ground-in seating K.

Hot Water Bib Valves, Screw Down.

This class of valve is very numerous, and they are nearly all made on the same principle as the screw-down cock,

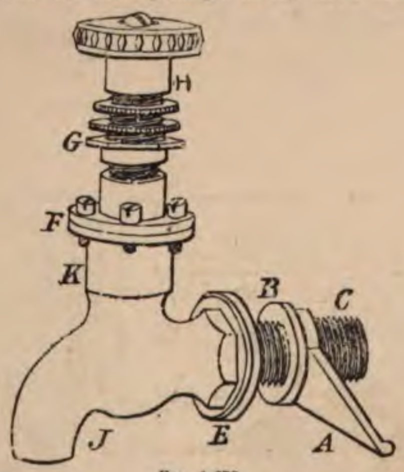


FIG. 1,678.

sometimes with ground-in valves, and at other times with *wired insertion rubber*. Fig. 1,678 illustrates a very good one, and I wish to draw your attention to Warner's patented boiler nut as shown at A. This is a very simple contrivance, to prevent the nut from turning round when the cock is being screwed off, &c., and is something that has been long wanted to be *made better known* to the public. The screw of the cock should never be longer than required for just the nut, so that fur cannot deposit on the screw to prevent it being unscrewed, and if it is longer it should be cut off before fixing. In judging cocks and valves, and when selecting these articles, always select those which will work nice and smooth, and without jumping or turning irregularly, for this is a sign that the key and spindles are not true, though in plug cocks it will happen through bad bottoming, and in Rotherham cocks through drunken threads, bent spindles, &c., &c.

Hot Water Cocks, Half-turn Screw Down.

Fig. 1,679 illustrates a range cock, which can be made with ground-in or rubbered valve. For section see Fig. 518. Fig. 1,680 is the same cock with short shank, thus

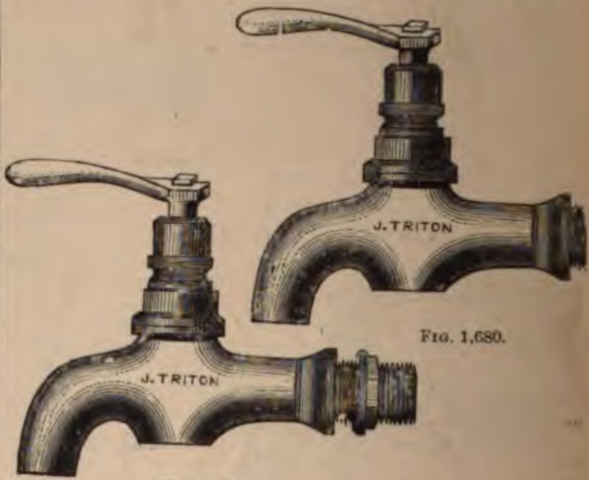


FIG. 1,680.

FIG. 1,679.

making it into a hob cock. Fig. 1,549c is a very good hot water cock, and may be had, if ordered, with a long screw and nut.

Ground-in, Range, Hob, and Horizontal Cocks.

Fig. 1,681 illustrates a ground-in S.B. hob cock, with boss for soldering on to lead pipes. The shank should be screwed for ¾in. or 1in. iron pipe, so that it may be used for iron or lead pipes.

FIG. 1,681.

Fig. 1,682 on the left illustrates a left-handed horizontal S.B. hot water cock with spanner, and on the right is a right-handed b[illegible] [illegible]antry horizontal cold water cock.

FIG. 1,682.

These cocks are used for butler's pantry sinks; the shank is or should be screwed for ¾in. iron pipe, therefore it will suit iron or lead pipe work. Also see Screw Down Horizontal Cock, Fig. 1,025.

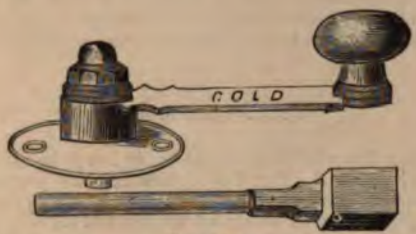


FIG. 1,683.

Bath Levers and Key Sockets.

Fig. 1,683 illustrates a bath lever and key socket—this is for turning the bath cocks with. They are made in suitable lengths, and welded together as required.

Boiler and Cistern Screws.

I have already referred to these useful articles, therefore a brief description will suffice.

The use of the cistern and boiler screw is to connect the lead pipe to the side or bottom of iron, slate, glass, earthenware, or other cisterns and boilers, and to such places that the lead pipe cannot easily be soldered. They are known as "long boiler screw," "short boiler screw with single nuts," also as "long or short boiler screw with double

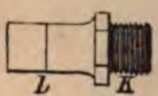


FIG. 1,684.

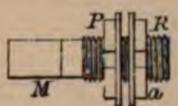


FIG. 1,685.

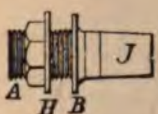


FIG. 1,686.

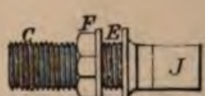


FIG. 1,687

nuts." Fig 1,688. This latter has flanged nuts and a left-handed thread, and is also stronger made at the thread part. The use of the long boiler screw, Fig. 1,687, is for such places as slate cisterns, whilst Fig. 1,686, the short, is for iron; it being simply the difference in the length of the threads from the shoulder B, to the end A, and also from E, to C, Figs. 1,686 and 1,687. At P, R, Q, Fig. 1,685, is shown the boiler screw with double nuts. The reason for having double-nutted boiler screws is for the purpose of enabling the plumber to screw up the nut from the outside of the cistern, &c., and also at other times, to enable him to regulate the height to which the thread may stand up in the bottom of the cistern without a lot of washers being used as packing, &c.

FIG. 1,688.

The manner of fixing the cistern screw is explained at Fig. 1,691, and description. Caution.—Never put the grummet on the side next the tightening-up back nut, for if you do you cannot very well screw the back nut up without cutting the grummet, unless you use a lead or other washer next the back nut, which only occasions additional trouble and expense. It may be well to say that this rule holds good with nearly all connectors, such as slate or iron cisterns, washers and wastes, spindle valves, &c.

Kitchen Boiler Water Supply.

Having shown various kinds of fittings, I have now to describe the fixing of the ordinary kitchen range boiler and supply. This class of kitchener or range boiler is to be

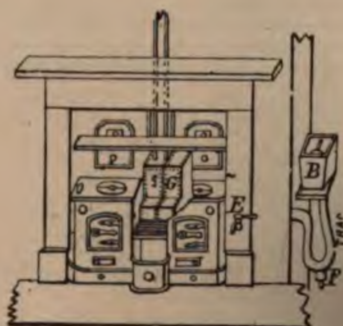


FIG. 1,689.

found in almost every good built house, and is [illegible] at Fig. 1,689

Feed Cisterns.

The feed-cistern is illustrated with lid complete at Fig. 1,691. B, or D, are the holes for connecting the supply pipe from boiler; E, is a slot for letting down the supply pipe to feed-cistern, so that the lid may shut down fair and close on to the top, to exclude black beetles, &c.; J, is the overflow hole, which, of course, may be in the end or otherwise. This feed-cistern is generally fixed with its top level with the top of the boiler. F, Fig. 1,689, is the trapped pipe connected to the feed-cistern by means of the short boiler screw, the nut of which is turned up with a key; or, if fixed in the side, with the boiler hook as illustrated at Fig. 1,690. (Also see Boiler Screw, Spanner and Pliers, Figs. 1,692, 1,693, 1,694, &c.) The jaws A, B, E, are

FIG. 1,690.

made in sizes to suit the various size nuts. It often happens that the hook will not turn the nut, owing to there not being sufficient room for the handle to work. Then this difficulty may be got over by the handles being crooked, and one also straight, as per dotted line J. A set of these hooks should be in every plumber's shop, for they often save a lot of time when taking out old boilers, &c. Should you not have a key to turn the nut when the hole is in the bottom of the cistern, then use a double-nutted boiler screw, as shown at P, Q, R, Figs. 1,685 or 1,688, and screw up from the outside.

Be sure to trap this pipe, if it is put into the side or front of the cistern, as at B, P, Fig. 1,689. This prevents the hot water returning into the feed-cistern, or, in other words, the weight of the cold water within the feed-cistern will then remain stationary, and will balance the hot water in the boiler, which stands at a higher level. The pipe F, is connected to the boiler with a boiler screw and a red-leaded grummet.

To these feed-cisterns, as at J, Fig. 1,691, within, say, 1in. of the top, should be fitted an overflow pipe, and, if of lead, must be connected with a *short boiler* screw fixed in such a manner that it cannot interfere with the working of

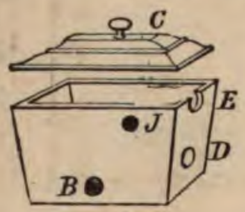


FIG. 1,691.

the ball-valve, and carried outside the house, and *not direct into a drain.* The feed-cistern should always, when practicable, be made self-supplying, with first-class ball-valves, such as shown at Fig. 1,037.

Fixing Range Cocks.

This is best done by making a good and tight-fitting hemp grummet, painted with red-lead paint, and slipped over the screw of the cock; then the nut put on, and the cock turned round until tight enough and in its proper position. Do not turn the cock so as to strip the thread or break the boiler. Fig. 1,671 is the class of cock to use; or if for very high pressure, perhaps a valve cock as shown at Fig. 1,678 will suit your work. Should the screw of the cock be too long cut it off, or fix washers at back of nut so that the screw cannot get furred to prevent unscrewing.

Bedding Down Common Kitchen Boiler Tops.

When doing this take care, first, to paint all round the top, then take some common putty and bed the top down. Some plumbers use red lead; but I think common putty is just as good, and is better from a sanitary point of view.

Boiler Manholes.

It often happens that a close boiler has to be used with manhole, as at J, Fig. 1,578, and for the purpose of supplying the scullery sink alone. When this is the case, an air-pipe must be taken off the top and carried up the chimney with a complete bend, to prevent soot falling into it. The feed-cistern must in this case be fixed at a higher level in order to force the water to its required place.

Boiler Screw, Hook Spanner and Pliers.

Fig. 1,692 is a pair of two-hole pliers, which are very handy for screwing up the nut of a single-nutted boiler screw when fixed in the bottom of the feed-cistern; but notice that they should be of large size, and open at the

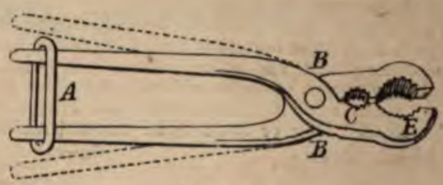


FIG. 1,692.

FIG. 1,693.

point of the jaws with the handles tapering towards the rivet, and a link may be employed to keep them together, as at A, when it may be seen that a lever placed between the handles may be employed for turning the pliers. Fig. 1,693 is a handy spanner, which will turn a boiler nut whether it be in the bottom or side of the cistern.

Fig. 1,694 (also see Fig. 1,690) is a spanner for screwing boiler-nuts in the bottom of feed-cistern, the handle of which is bent over, as at B, which should be bent to come upright with the centre of the square, as about D, so that the nut may be turned and the handle kept at one common centre.

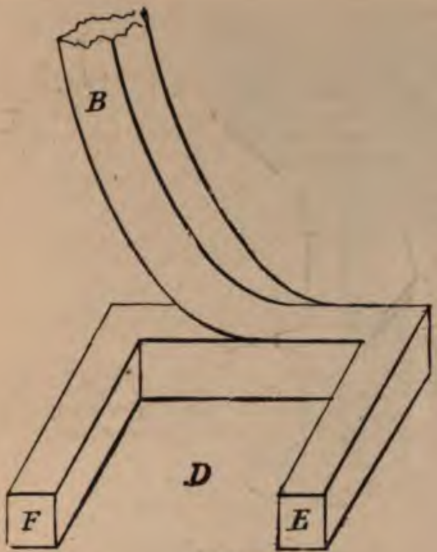


FIG. 1,694.

Double Boilers.

Sometimes it will be found more convenient to fix two boilers, as at G, S (Fig. 1,689), one for the kitchen and scullery work, the other for the baths, &c. This often prevents squabbling with the servants, inasmuch as they cannot use each other's hot water, for it sometimes, and not unfrequently, happens that the cook or scullery maid will use the hot water very indiscriminately, and so leave the other servants, &c., to do as best they can. All this is prevented by the use of the second boiler, to say nothing about the difference in the lasting of the scullery sink hot-water cock, by reason of its working under a low pressure against that of high.

Steam Kettles.

I shall now introduce to your notice some heating apparatus for cooking by hot water or steam, suitable for hotels, builders, printers, oil mills, water works, and in fact for every place where cooking is done, and where steam may be had.

Fig. 1,695 illustrates Bailey's patent kettle, showing the steam jacket at STEAM; it also shows the hot water at HOT WATER BATH. This water may be used for various purposes, such as for boiling potatoes, greens, soup, and the like; or it can be used in builders' or cabinet makers' workshops, or in any place where fires cannot be had.

Fig. 1,696 illustrates the steam kettle as used for workmen's meals. The steam, of course, may be had from an ordinary portable or other engine boiler.

Steam Kettles and Ovens.

Fig. 1,697 illustrates a steam hot plate on the left, also an oven on the right, as used at the India Mills, Over Darwen; also at many of our largest manufactories about London, Manchester, Nottingham, Bolton, Oldham, &c., and are universally liked wherever used. Of course, any number of ovens can be heated in this manner, and may be had with two or more pillars. These ovens work upon the same principle as that illustrated at Fig. 1,695, there being a steam jacket all round the sides, back, bottom, and top of the oven.

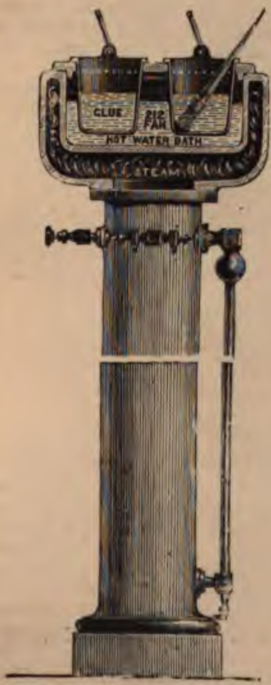


FIG. 1,695

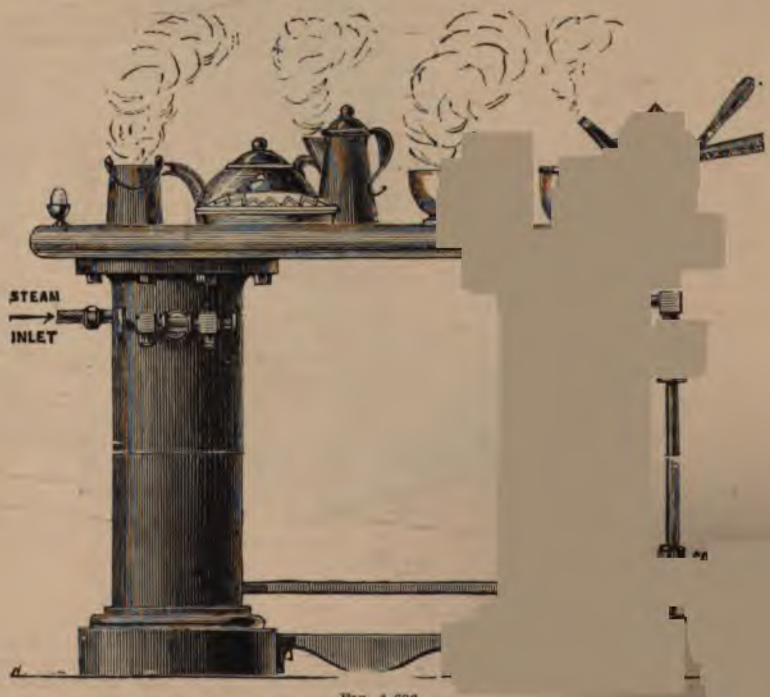


FIG. 1,696

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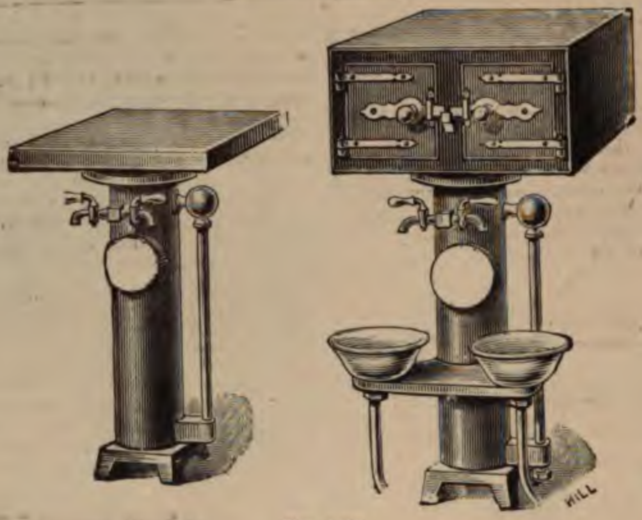

FIG. 1,697.

FIG. 1,698.

It will readily be seen that if the steam kettle or ovens be placed in the centre of a workshop, that it will keep it warm, so that it may be said that it possesses the following advantages:—That it is always ready for work when required; it will cook food with the least attention; it warms a shop or other place.

The action of these kettles is as follows:—Connect the steam pipe on, as at STEAM INLET, Fig. 1,696. The

steam then finds its way all over the internal parts, and in time condenses into the bottom as at CONDENSED STEAM. Here water accumulates, and as it rises it lifts a float, which opens a cock and thus allows the condensed water to run away; of course, when cocks as shown at Fig. 1,697 are to be supplied with hot water, they work on the same principle as those shown at the STEAM KETTLE on page 318, and are there well described.

Fig. 1,698 illustrates Bailey's steam water heater, with the outer case cut away to show the worm. It also shows the feed-cistern as fixed to supply the water, and the inlet and outlet for the steam connections.

Heating Water by Steam Pipes.

(DRY STEAM.)

Of course you may boil water by passing steam through a coil of pipe submerged in a tank, the pipes being laid in coils or otherwise round the bottom, or a coil similar to that shown at Fig. 1,699, placed in a tank; this is often done for the men to wash in oil mills, petroleum oil stores, tar distilling works, &c., often a simple coil of ¾in. or 1in. lead pipe being merely connected with a union to a steam pipe, the top part of the coil being brought over the top of the tank to convey away the condensed water. And if the outlet of this be reduced (not too much or your pipes will burst), the water will heat more rapidly.

Boiling by Wet Steam.

In gas works, where the men require a drop of hot water quickly, they simply take a pail of cold into which they dip the end of a steam pipe, turn on the steam tap, and in this manner get a pail of hot water in a few seconds. It is also practised in laundries, and the same dodge is practised by engine drivers when they cannot obtain clean water from the boiler.

This system is attended with loud noises at the first start and until the water boils (see Water Hammer).

Water Heating by Injectors.

(WET STEAM, *continued.*)

I have just said that by placing the nose of a steam pipe into a vessel of water, that on turning on the steam a loud noise is heard. To get over this difficulty, and indeed on large works (where boiling by *wet steam* is practised), and to prevent the pipes from splitting, I twenty-seven years ago introduced a kind of injector, which I then wrote about in the *English Mechanic* and called it a flood pump, the injector having a mouth for the liquid to enter, and a smaller pipe for the outlet of the steam and induced a current of water, so that the noise is reduced to a minimum, and the pipes prevented from splitting. This also gives great agitation of the liquid, a very desirable acquisition in some chemical works, such as sulphate of copper, sulphate of ammonia, and other works.

The injector may be made with a simple elbow placed within a common iron tee, in such a manner that the liquid may pass through the tee longitudinally, the elbow being in the centre of the tee, and a piece of trumpet pipe on the inlet of the tee.

This noise may be greatly reduced by piercing a pipe with *small* holes for the steam, or by a garden watering pot kind of rose.

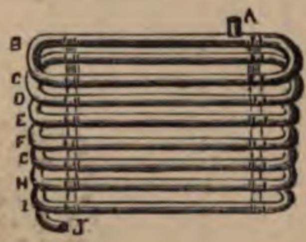

FIG. 1,699.

INJECTORS AND EJECTORS.

These articles have been in use for many years, and may date back to the early days of the blacksmith's forge, having a tuyere; for the nose-pipe from the bellows, entering the cone, or tuyere, is certainly at times an injector.

Next in order of age, let the steam exhaust from the blast-pipe of a locomotive engine be studied. Here the blast-pipe is an injector, or rather ejector, date about 1830. Next we hear of its use in Howard's Vacuum Pans, and in the year 1835 we find Thomas Ewebank, of New York, at work experimenting, but whose wind was taken out of his sails by M. Pellatans, who read a paper thereon at the Paris Academy of Arts and Sciences, January, 1833. Next of any note is Giffard, whose injectors to supply water to steam boilers are, or should be, known by every mechanic.

Injectors for Heating Water.

We have seen (if not heard) the effect of heating water by steam exuding through the open end of a simple steam-pipe, and the terrible row it kicks up, but it would be simply useless for me to say it does make this noise, and it is now my duty to show you how to alter it, and the following is the best known means.

Acid Injector.

Fig. 1,700 is an injector. I fixed twenty of these injectors at Morfa Copper Works, Swansea, for Messrs. Williams, Foster & Co., about seven years ago, and found them to work very well on lifts about 18ft. throwing sulphate of copper liquor. There was used $\frac{3}{4}$in. stout ($\frac{3}{8}$in. thick) lead steam pipe at S, and 2in. lead pipe for suction at I, N, and $1\frac{1}{2}$in. for rising main at O. The suction and rising main pipe being $\frac{1}{2}$in. thick lead, though a much lighter pipe would have answered for the suction. The parts are as follows:—A, A, is an antimonial hardened lead casting $\frac{1}{2}$in. thick, and $\frac{3}{8}$in. flanges F, F, F. N, is the steam inlet nozzle made with very hard lead (antimonial lead); the outlet of this nozzle is about $\frac{1}{8}$in. to $\frac{3}{16}$in. diameter. All this is securely fixed between

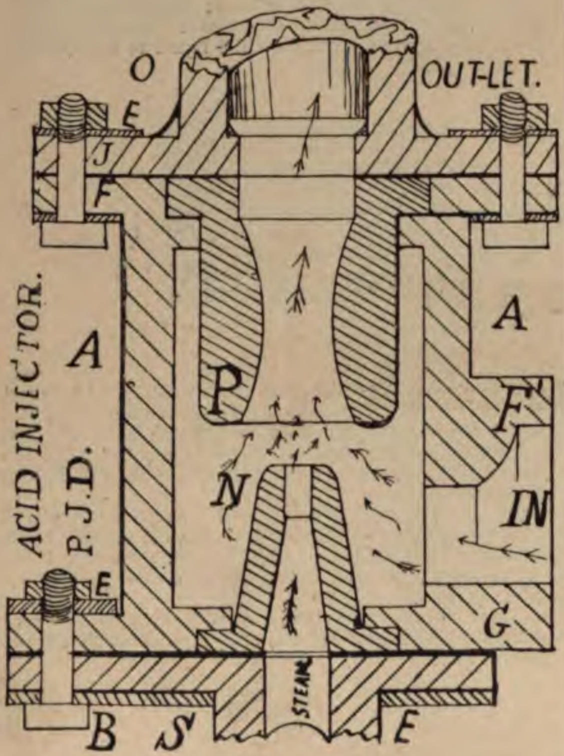

FIG. 1,700.

the flanges with the bolts and nuts B, F, A, with an extra iron flange E, E. The suction pipe is also flanged and bolted on with two iron rings as at G, and rest firmly on the lower liquor tank—*important*. The cone P, is made of earthenware, well glazed and about $\frac{3}{8}$in. thick at every part, and is also fixed between flanges with iron flange E, to give additional strength, and all bolted securely together as described and shown.

The action is as follows:—Assuming the whole put together as explained with a steam cock at S, the inlet IN. dipping into a lead tank of liquor, and the outlet O, bent over the top of another lead tank; turn on steam from a boiler having a pressure of say 30lbs. per square inch, the steam rushes through the nozzle N, and increases in volume in P, and causes a partial vacuum in the suction pipe I, N, and "away" up comes the liquor from below, and so plays round the front of the nozzle N, shown by the arrows; then the condensation and the pressure of steam from the boiler, which also becomes *contracted* at the nozzle N, by which its velocity is greatly increased and the liquor becomes mingled with the condensed steam, and consequently the liquor is driven with great force into the cone P, and up the rising main into the top tank.

The Principle of the Injector.

The velocity of escaping steam under a given pressure is considerably more than that of hot water from the same boiler, and at a pressure of 80lbs. to the square inch the velocity excess would be about as 8 is to 1. It must be remembered that the escaping steam, when it is suddenly being condensed by coming in contact with the cold liquor, loses none of its *outward* velocity, save friction from the nozzle N, and, therefore, as a consequence, after condensation, it has a highly penetrating force of about eight times greater than water would have from the same boiler; hence why an injector appears to work against itself when used to drive feed water into steam boilers.

It must also be remembered that the moment of condensation it imparts its acquired momentum to the liquor by which it is condensed and with which it freely mingles, and so *warms* up the *liquor* or water; hence why they are used for boiling water—to be explained.

Further, 1,700 cubic inches of steam will, on being condensed into a cubic inch of liquor or water, impart momentum enough to drive and exactly balance the eight cubic inches of water by which it was condensed, against the same boiler from whence the steam actually came, but here the imposing forces would be in equilibrium; but take a less quantity of water, say 6in., then the steam momentum will overbalance the resistance of the boiler water, and the mingled steam and water will flow onward and into the boiler.

Now you have seen how the injector works, it will be plain that the liquor must be slightly warmed up by the amount of steam taken up by the water, and this being so, let us go another way to work with regard to the suction and rising main. Instead of the suction going into a separate tank to throw water, let the injector be fixed horizontally within the tank containing the liquor to be boiled with short lengths of suction or outlet, then turn on the steam, and a continuous flow of cold and hot water takes place until the lot boils, thus nearly doing away with the noise of the water hammer, of which more anon.

Sometimes it will happen that you cannot fix the injector or water heater within the tank. When such is the case the injector may be fixed as shown at Fig. 1,701, on the side of the tank, or as you please.

You see in Fig. 1,701 a somewhat differently made water-heater. This is made by Messrs. Korting Brothers. A larger view is shown at Fig. 1,703, without the second flange and nuts, whilst the figure 1,704 (sometimes made with porcelain) the whole is complete and ready for fixing the injector to flanged leaden pipes.

Refer to Fig. 1,701. At L. is small air inlet valve on top of a small pipe. This valve is shown in the enlarged view Fig. 1,702, and is to admit a very small quantity of air into the injector just at the steam inlet; see Fig. 1,703 at L, and by this the water hammer rattling is quite avoided up to a boiling point.

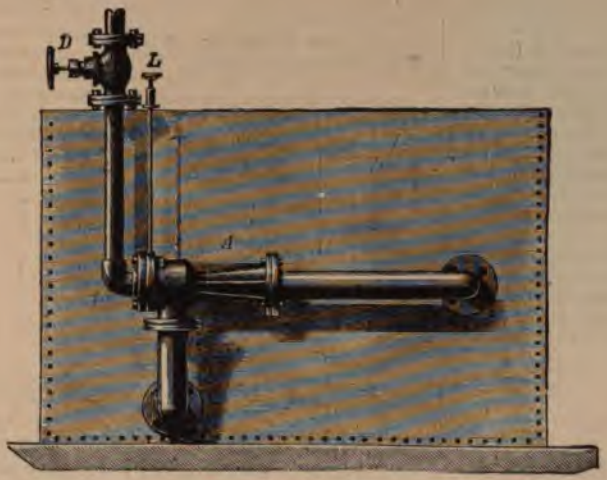

FIG. 1,701.

FIG. 1,702.

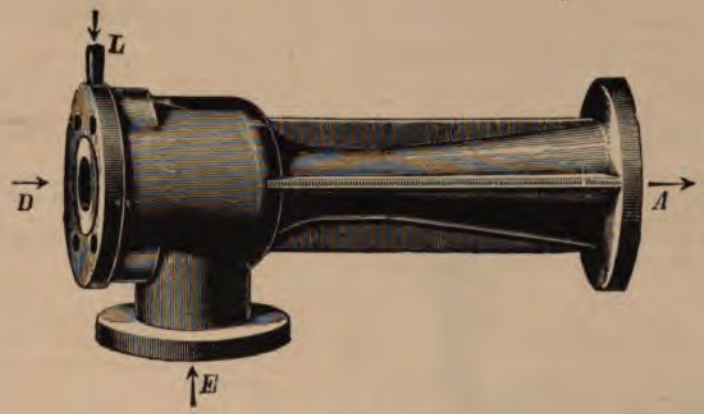

FIG. 1,703.

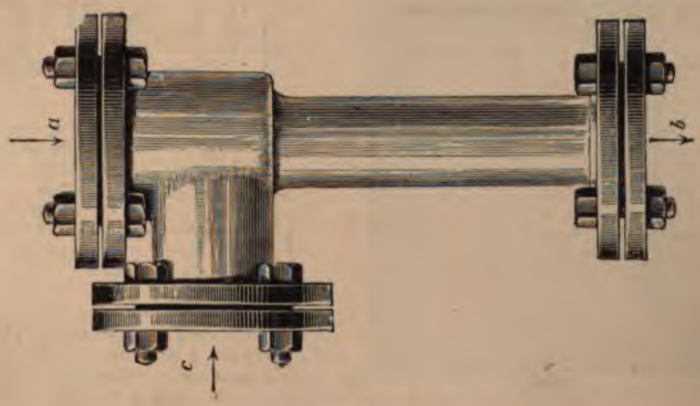

FIG. 1,704.

Silent Steam Water Heaters further explained.

I have at length explained the water hammer (which see), but will again briefly touch upon the theory and principle on which the water heaters work. It is that the steam being introduced in the form of a jet secures for itself a continuous and steady condensation by inducing a current of water or liquor through the injector; then the rattling or shaking, due to the irregular condensation and sudden collapsing of steam bubbles, which occurs when the steam is sent through an open pipe into the water, is almost entirely prevented.

There is, however, with the ordinary jet injector water heater a certain amount of irregular condensation, and consequent noise, when the temperature of the water gets near to a boiling point, which is quite dispensed with by the introduction of Korting's valve, Fig. 1,702, for air supply.

Rules to be observed when Ordering.

1.—Whether the heater is to be placed inside or outside the tank.

2.—Pressure of steam at the heater.

3.—Size of heater or number of gallons to be he per hour.

4.—Initial temperature of water.

5.—Final temperature of water.

Size of Heater.	Number of galls. heated per hour to boiling point.	Inside diameter of steam pipe.	Inside diam of water p CLASS B he
No. 1	125	$\frac{3}{8}$ in.	$1\frac{1}{2}$ in.
,, 2	250	$\frac{1}{2}$,,	2 ,,
,, 3	500	$\frac{3}{4}$,,	3 ,,
,, 4	750	1 ,,	$3\frac{1}{2}$,,
,, 5	1250	$1\frac{1}{4}$,,	5 ,,

Acid Porcelain Injectors (*continued*).

Fig. 1,705 is Korting's porcelain acid injector above a tank for forcing acid to a higher level; *d*, i steam pipe; V, the shut off valve; S, the suc D, the rising main.

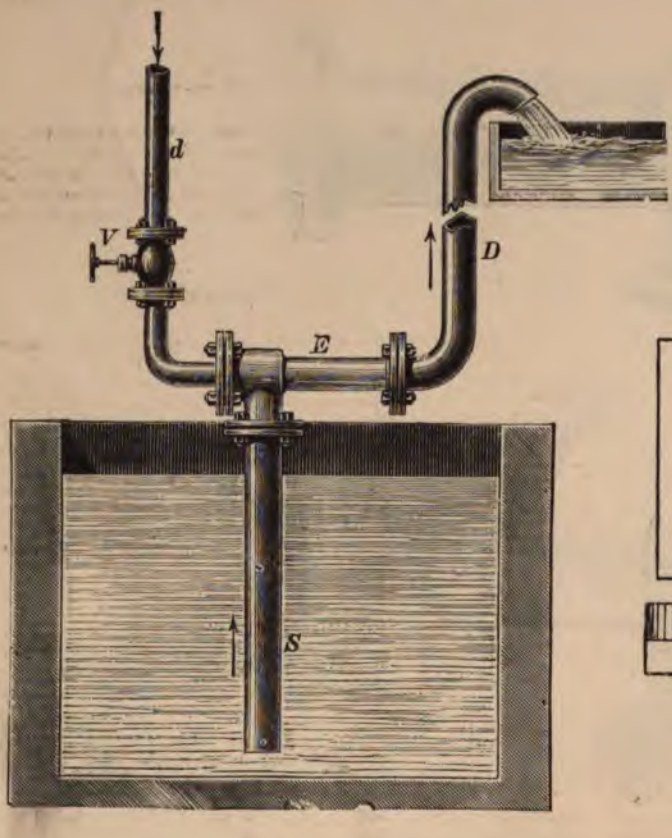

FIG. 1,705.

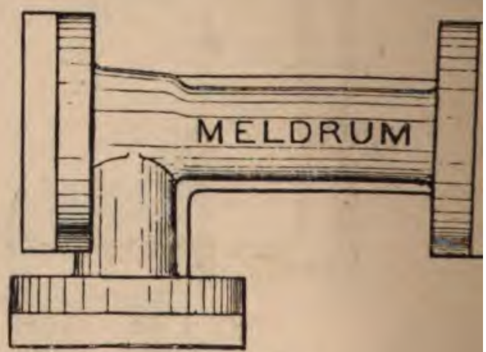

FIG. 1,706.

Meldrum's High Lift Acid Injectors.

Fig. 1,706 is one of Meldrum's celebrated acid injectors made very strong and in regulus metal, and Fig. 1,707 is an illustration of a job I did at the Morfa Copper Works, Swansea, for Messrs. Williams, Foster & Co., Limited. I personally put up a large number of these injectors for lifting sulphate

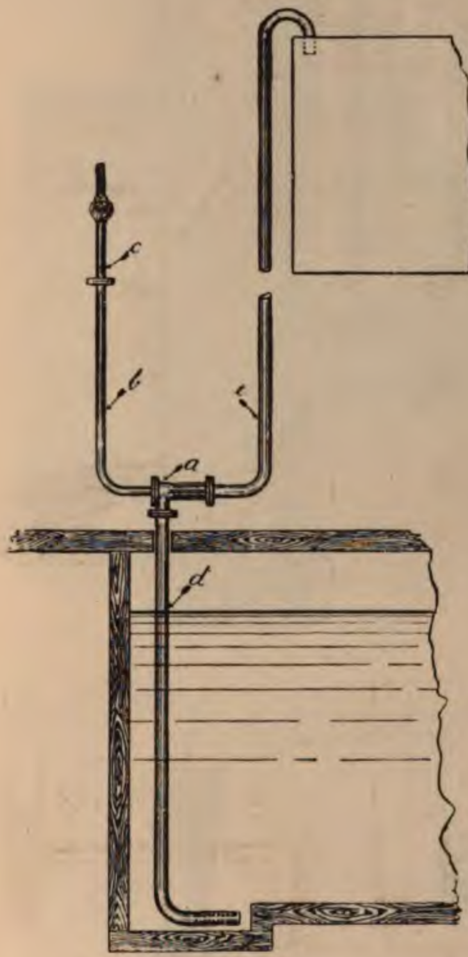

FIG 1,707.

of copper liquor to tanks above the towers. They draw and lift water fully 40ft. perpendicular through a 1½in. leaden pipe fully ½in. in thickness, with burnt joints, and give great satisfaction: *a*, is the injector; *b*, the steam pipe, having a back check valve at *c*, to prevent the acid backing; *d*, the suction pipe.

Cortin's (*note the distinction in names*) Regulus Metal Injectors.

Fig. 1,708 is Cortin's well-known reliable acid injector, suitable for raising heavy acids, and especially suited for sulphate of ammonia plant. I have personally fixed a large number of these at gas works about England, Scotland, Wales, and especially Ireland. At the Alliance Gas Works, Dublin, one of the most modern sulphate of ammonia

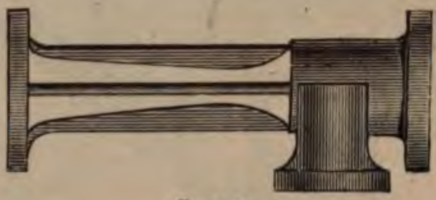

FIG. 1,708.

works in the world, there I fixed some for Messrs Samuel Cutler & Sons, Engineers, Millwall, London, some years ago, and these injectors are as good to-day as when put up, except having a new nozzle or two put in, which any intelligent labourer can manage. I should here state that the only parts liable to wear away, is at injector nozzles, and is common to all injectors.

Air Injectors and Blowers.

You have seen the different sorts of steam injectors and how they work, I will now add that these injectors can be made to draw or force air just as they did water, or instead of steam, compressed air may be used in places where the wet steam would too much weaken the acid or other liquor, or otherwise.

Water Pressure Jet Injectors.

To pump water by water may at first sight appear strange, nevertheless this is to be done as follows.

Fig. 1,709 is an injector whose motive power is due to a high pressure stream of water passing through the pipe D, and apparatus E, at a great velocity, which will cause a vacuum which sucks the water to be lifted up the pipe S, and then forces it forward through the pipe G. As may be seen, this water jet elevator may be used with considerable advantage in close places, such as mines, tunnels, and the like, see R, A, V, B, D, E, G, C, &c.

These injectors are also very useful to drain a cellar which may be below the main sewer.

Fig. 1,710 illustrates the water jet injector on such a job. B, is an ordinary street main supply; E, the injector: R, D, the raising main. Fig. 1,711 is the injector enlarged showing the inlet high pressure inlet A, the outlet B, and the strainer C. These very cheap little pump jets are made by Messrs. Korting Brothers.

No.	Water delivered per hour. galls.	Minimum inside diam. of tubes high pressure water.	Diameter of tube discharge.
1	200	⅜ in.	¾ in.
2	400	½ ,,	1 ,,
3	1,000	¾ ,,	1¾ ,,
4	2,000	1¼ ,,	2¼ ,,

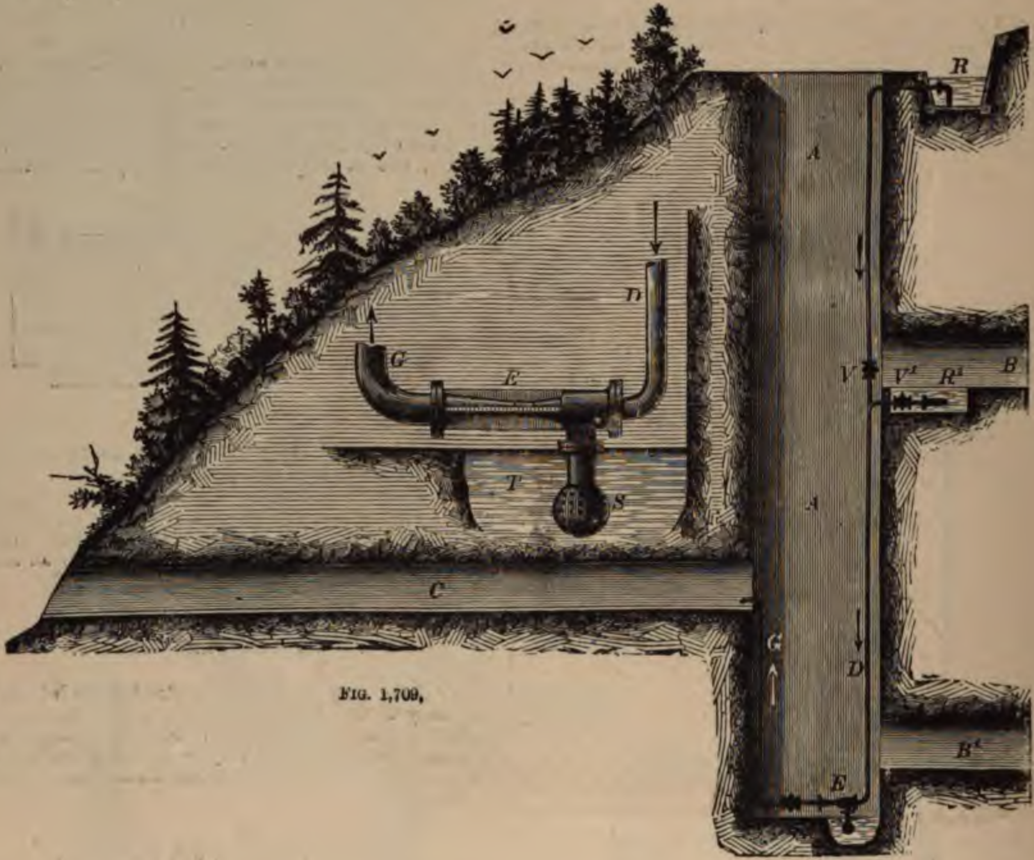

FIG. 1,709.

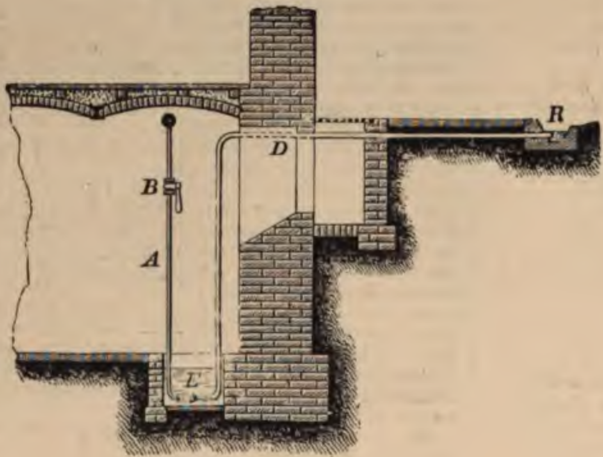

FIG. 1,710.

FIG. 1,711.

Sizes and Work.

In order to know what size you should use, you must know the following :—First, head of water or pressure on the water main ; secondly, the height to which you require the water lifted.

You must be careful to keep the inlet or blast holes free from dirt and such like, and fix the jet as low as possible in a deep cavity. Should the jet suction get choked up, just for a moment close the rising main at R, Fig. 1,710, and the pressure will soon clear the blast holes. Also see Fig. 923c.

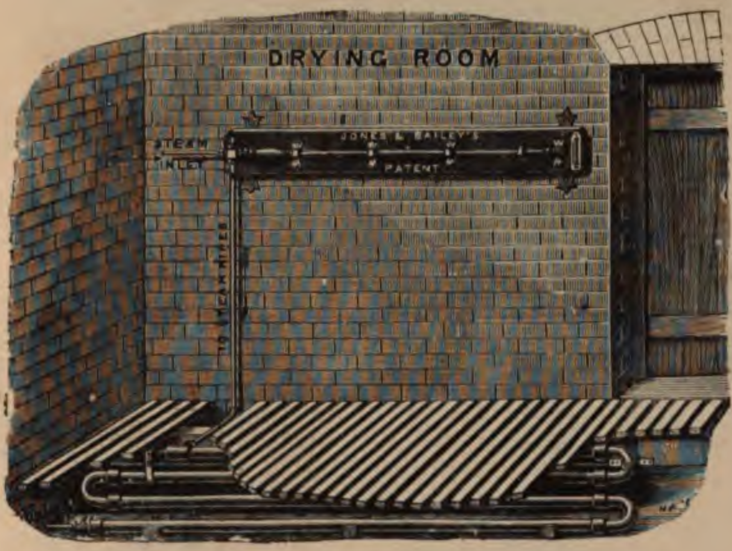

FIG. 1,712.

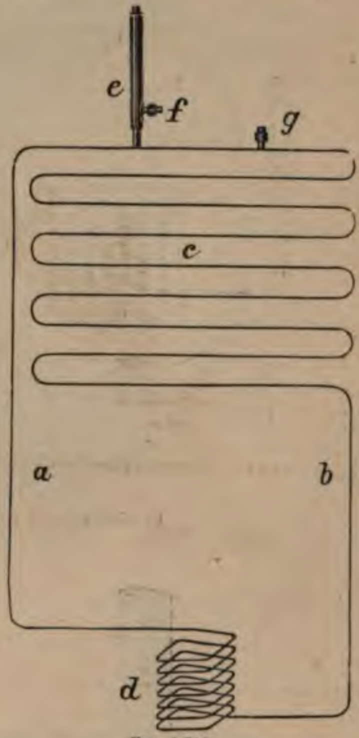

FIG. 1,713.

Laundry Drying Rooms.

There are various kinds of drying rooms. Fig. 1,712 illustrates one arranged by Messrs. Bailey, and is so managed that by the use of their Thermostatt or Automatic Temperature Regulator, it can be kept to one uniform heat, and can be worked by steam or hot water; Fig. 1,712 being arranged to work with steam.

When these steam or hot water pipes are used, care should be taken to well ventilate the room, by providing a fresh air inlet near the bottom and a large outlet near the ceiling. This will keep the room from sweating, and the clothes will dry readily.

Heating by Hot Water.

There are scores of methods of heating by hot water to suit the various places required to be warmed. For instance, you have only to turn to Fig. 1,624, where you will see hot water pipes running in all directions, which will heat the compartments according to the length and sizes of the pipes. Also examine Fig. 1,572 ; in fact, any of the large diagrams will give the reader an insight into the principles of heating by hot water. The principal thing to keep in view is quick circulation. I will therefore begin by at once introducing my reader to the late Mr. Perkins' system, and, although it is Perkins' I shall show Mr. Gibbs' work here (Fig. 1,713), which is known as the high-pressure system in its simplest form. This, as can be seen, is simply an endless pipe of small diameter, $\frac{3}{4}$in. or $\frac{7}{8}$in. inside bore, and, say, $1\frac{1}{8}$in. to $1\frac{1}{4}$in. outside diameter, screwed together with left and right handed threads. The form of the boiler can be seen at *d*, and is nothing but a cage or a coil of pipes, bent to form a boiler of pipes or to contain the fire, whilst by far the larger quantity of piping is taken to various places for the heating purposes. For instance, the flow pipe will be seen to come off the top of the boiler coil, it then rises as at *a* ; it then passes on to the 3in. or 4in. air-tight expansion tube *e*, *f*, which is for collecting the small bubbles of air, and also to make room for the *expansion* of the water, which takes place as it becomes *heated*. Of course, if it were not for this expansion tube the pipes must burst.

On this expansion tube at *f*, is fitted a strong ground-in plug or a valve, for allowing the air to escape when filling the pipe, therefore this should be the highest point of all the pipes. *G*, is the filling cap, which is fitted with a plug, or at times it will be safer to fill the pipes from below, say somewhere on the pipes *b*, or *a*. This filling is done with a force pump, care being taken to keep pumping until all the air bubbles are expelled out at the air valve *f*. Of course, the boiler coil is built in brickwork, in a similar manner to that shown at Fig. 1,714, so that the fire can get all round both sides of the pipes. Or instead of brickwork the pipes may be enclosed within an iron case, as shown at Figs. 1,715 and 1,716. This is Renton Gibbs' furnace, and is largely used in many of our largest public and private buildings, and is well worthy of your notice, as he is a master at his work.

This system of hot water heating requires less water than any other, 500ft. of piping can be kept going with half a pint of water per week, which is easy to replenish without making a mistake.

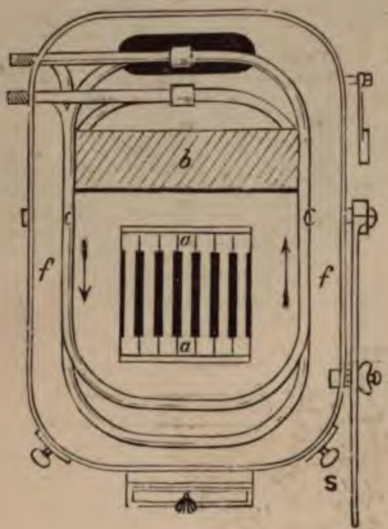

Fig. 1,714.

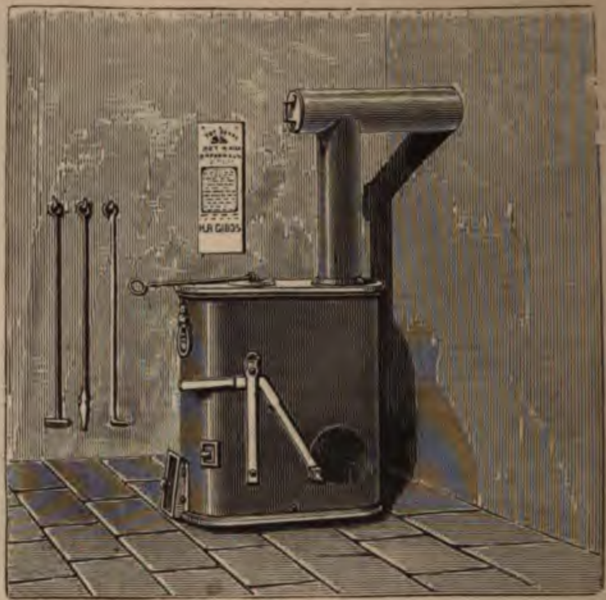

Fig. 1,715.

Fig. 1,716.

Hydraulic Press Pipe Joints.

In this system of hot water work it is very important to have tight joints, as the least leakage would spoil the action of the apparatus. Besides, with this system, there is at times a very heavy pressure, due to the fact that when the water expands it only is allowed to expand into the air-tight expansion tube, and in order that the joints should be perfectly sound, and remain so, the inventor, Perkins, adopted a left and right handed screw for the ends of his pipes, and used a copper disc for the end of the pipes to grind or cut themselves into, similar to the pointed end in Fig. 1,717. Or at other times the one end of the pipe is made with female cone and male cone, to cut itself into the end of each other, and so form a perfect joint without a copper disc or other packing media.

Sizes of Furnaces for Heating Different Lengths of Piping.

Length of Furnace.	Width of Furnace.	Height of Furnace.	Length of Pipe Heated.
1ft. 6in.	1ft.	2ft. 6in.	325ft.
1ft. 6in.	1ft. 3in.	3ft. 0in.	425ft.
2ft. 9in.	1ft. 9in.	3ft. 3in.	700ft.
3ft. 6in.	1ft. 9in.	3ft. 6in.	1000ft.
5ft. 0in.	2ft. 6in.	3ft. 9in.	2000ft.
5ft. 6in.	2ft. 6in.	3ft. 9in.	2500ft.

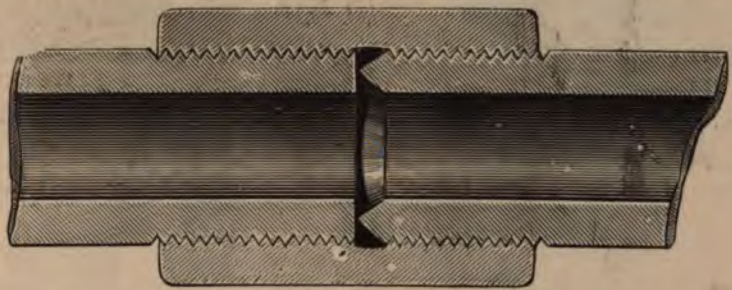

FIG. 1,717.

Hot Water Circulation (Cause of).

The action of this system is as follows:—Suppose the pipes to be full of water and a fire going, the water soon gets hot and thus expands, and at once becomes of less specific gravity. Therefore if the water expands, and becomes lighter for its bulk, it must necessarily rise up the pipe *a*, Fig. 1,713, which it does, and thence round or along the pipe *g*, and down from *g* to *c*, thence to *b* and again to the boiler, where it again gets heated, and still becomes of less weight bulk for bulk. Consequently the water within these pipes is constantly on the move, and flows at a rate to be determined by the difference in the temperature and consequent density of the ascending and descending columns of water within the pipes *a* and *b*. Of course, the water at the commencement of lighting the fire moves slowly, increasing in velocity at each circumvolution, and will continue increasing until a point in temperature is reached, when the water can absorb no more heat during its passage round the fire coil. Here the water becomes stagnant, and remains so, as long as the equilibrium is established between the two columns of water.

Circulation of Water Reversed (Cause of).

The moment one column becomes the least colder than the other the water again is set in motion, whether it be the flow or return; therefore, you see, that it is quite possible to reverse the action of the hot water within a flow and return pipe. This is often done in the ordinary hot water work, when there happens to be a draw-off fixed on the return pipe, and I have seen it continue for hours together working in this fashion

I may say that I have always worked to near about these sizes, and have always found them to work satisfactorily, and if the furnace bars and flues are properly arranged will give perfect satisfaction. At one of my hot water jobs, namely, at the Hospital for Incurables, Putney Heath, I found the above sizes sufficient to work 25 per cent. more piping than I expected it to do, which extra pipe was added after I had completed my first contract, and to this day continues to work well, although now nearly twenty-nine years ago.

Wrought Iron Welded Independent Boilers, known as Newton, Chambers & Co.'s Olympian.

This boiler, which is Messrs. Foster & Dawson's Patent, is shown at Figs. 1,718 and 1,719. It is very powerful, effective, and economical, and I can recommend
the water is not too hard to cause much fur,
most suitable boilers for churches, public
mansions, and greenhouses. N.B.—I hav
your attention to the fur deposit. but if
caution necessary (see Chemical Work of W
this work), you can use something to preve
will not injure the work. I leave you this
for yourself.

FIG. 1,718.

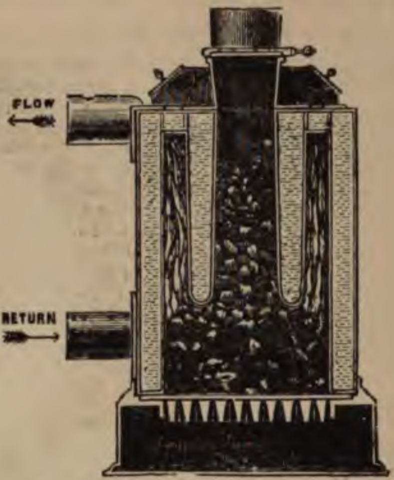

FIG. 1,719.

Tubular Boilers.

Fig. 1,720 illustrates Renton Gibbs' tubular boiler, and Fig. 1,721 is a section of the same. These boilers are made to heat from 1,500ft. to 4,000ft. of piping, an consists of a horizontal ring of tubes, connected togethe at their ends, that the water to be heated shall circulat from one tube to another until it has passed the whole c

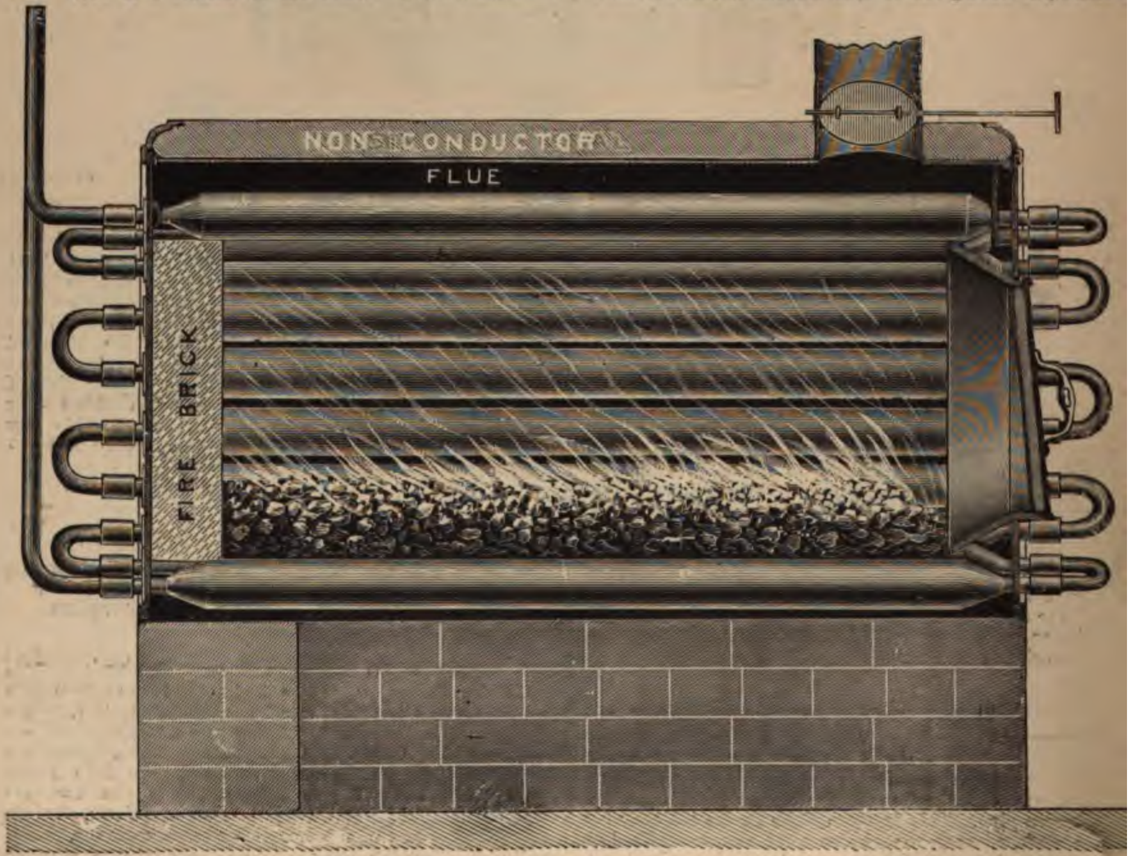

FIG. 1,720.

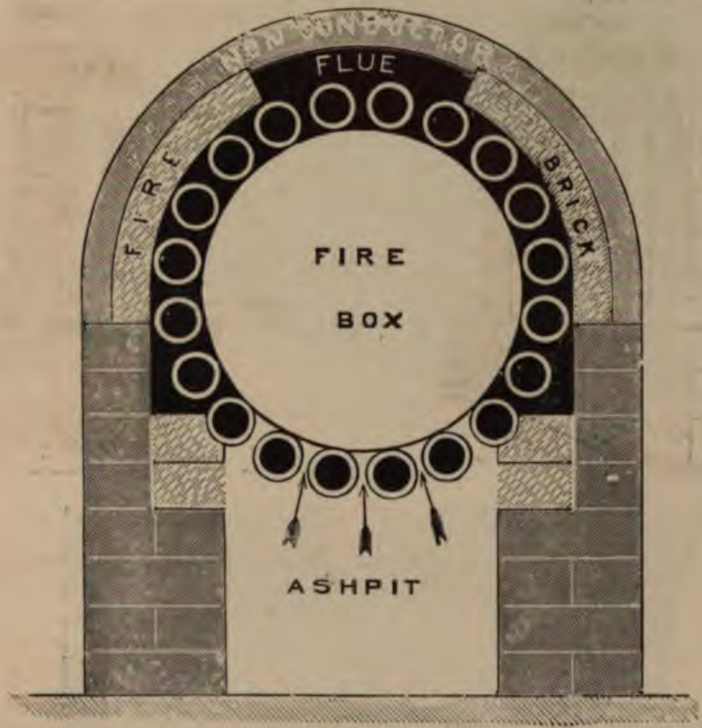

FIG. 1,721.

the tubes; or the rings may be divided into groups in such a manner that each group has an independent circulation.

When the water circulates through the cylinder of tubes in the manner first mentioned, a single flow and return pipe is used for conveying it round the building to be tinuous circulation through the whole, or any desired part of the whole of the tubes, instead of having an independent circulation for each group.

It will be seen that this circle of tubes forms the internal part of the fireplace.

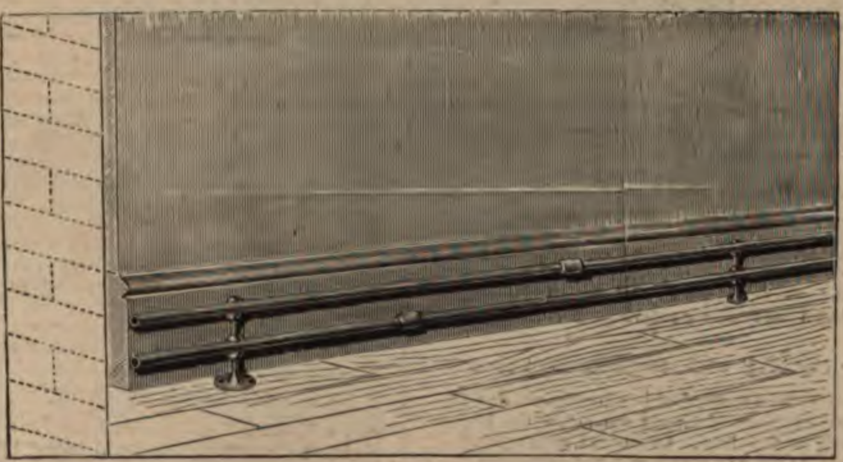

FIG. 1,722.

heated; but when the tubes are divided into groups, a flow and return pipe is employed for each group.

If desired, the flow pipe of one group may be connected to the return pipe of the other, and so on, to cause a con-

Fig. 1,722 illustrates the pipes supported every 7ft. or 8ft. upon iron standards screwed to the flooring, and Fig. 1,723 illustrates the piping suspended upon wall pipe brackets and needs no further description.

FIG. 1,723.

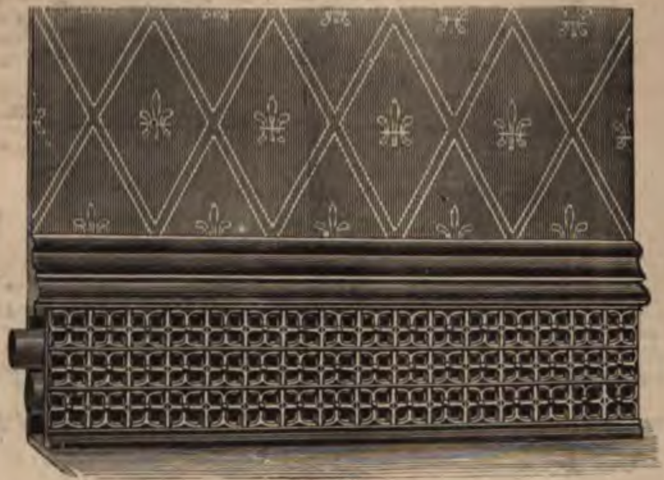

FIG. 1,724.

Fig. 1,724 illustrates the pipes as fixed for a private house. Here it is necessary that the pipes should be covered with something a little more ornamental than the bare pipes themselves, so they are in this case placed behind an ornamental iron case, which may have any kind of top. This is from one of Renton Gibbs' arrangements, as is also Figs. 1,725 and 1,726.

Fig. 1,725 illustrates the piping fixed on pipe brackets, with the iron or other casing away.

Fig. 1,726 illustrates the pipes fixed between the skirtings, and also shows the fresh air entering at AIR BRICK.

Hot Water Heating with Registered Stove.

Fig. 1,727 illustrates a method of heating by water with pipes fixed in an ordinary sitting room stove, the boiler being simply hollow fire bars. Of course such arrangement can be made to fit any stove, and the heat from the fireplace can thus be communicated from this room to that above, or even below. Of course the pipe must be taken upwards first, and be made to work upon the same principle as shown at Fig. 1,590—the flow goes up, and the return must be continued to be taken downwards and up again. This is a drawing from one of Renton Gibbs' stoves.

725.

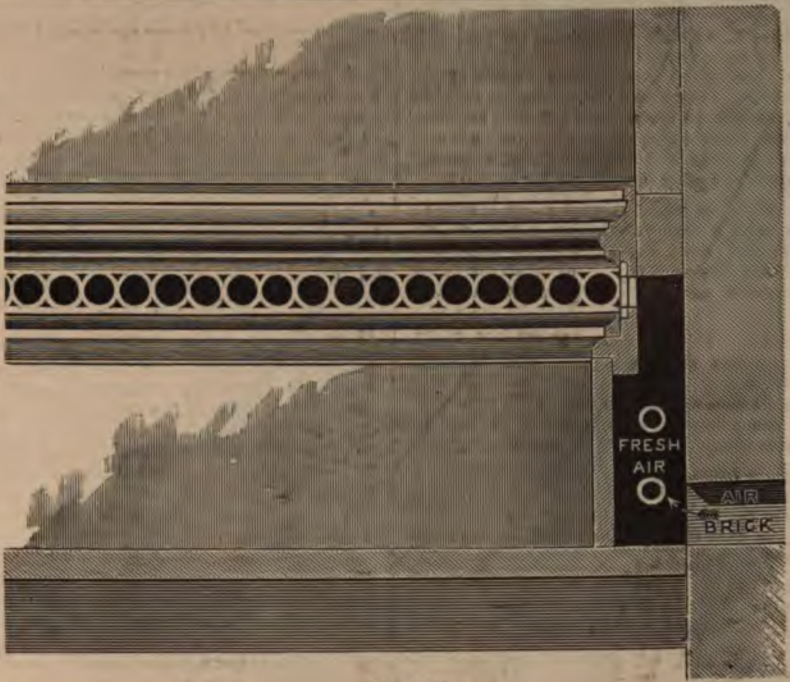

FIG. 1,726.

FIG. 1,727.

Heating by Radiators.

The quantity of heat radiating surface necessary to warm a room in winter, to say about 60°, when the outside atmosphere is 32°, should be for a foot square of surface, heated to 200° for every 6 feet of window glass, or as much heat for every 120 square feet of wall or ceiling, allowing 6 cubic feet of air to be escaping per minute for ventilation.

Any method of warming without ventilation is sure to give dissatisfaction, and where ventilation is effected by doors, or windows, and open fireplaces, very often the remedy is as bad as the disease, a supply of fresh air being obtained at the expense of cold draughts, with their attendant evils.

The vital importance of an abundant supply of fresh, pure warm air to public buildings, hospitals, schools, churches, manufactories, workshops, offices, mansions, and ordinary dwellings, needs no demonstration at the present day, sanitarians of every school being agreed that healthy animal life can only be preserved in a salubrious atmosphere.

A pure atmosphere is composed of 21 parts of oxygen and 79 parts of nitrogen, in a state of mechanical mixture, with traces of ozone in the most healthy; whereas carbonic acid and other deleterious gases are to be found in the most unhealthy neighbourhoods.

The composition of air in confined spaces is changed and vitiated by respiration, by the gases and effluvia exhaled by the skin, by artificial lights and fires, by the putrefactive fermentation of vegetable and animal substances, and sewer gases.

A person sitting in a room inhales 600 cubic inches of air per minute, or 500 feet passes through the lungs in 24 hours, and is deprived of 5 per cent. of its oxygen, and is further deteriorated by an equal quantity of carbonic acid, and along with this a quantity of aqueous vapour contaminated with the most offensive animal effluvia, which is separated from the blood, amounting to one pound weight from the lungs, and a pound and a half from the skin in 24 hours. A small lamp or candle requires 1 cubic foot of air per minute, an ordinary gaslight, 5 cubic feet: thus the air we breathe is deprived of its oxygen, and loaded with poisonous gases, by every process of combustion and decomposition.

When a ray of sunlight falls into a darkened room, it reveals myriads of animal and vegetable molecules, which were before invisible. These microscopic germs in badly ventilated places are the authors and agents of corruption and disease. Not less than 10 cubic feet of fresh air is required per head per minute to dilute and render wholesome the atmosphere in a room, and in a sick room or hospital more than twice this quantity is necessary. A safe general rule is to change the air in any living room about four times in an hour.

The radiator, Figs. 1,728 and 1,729, is specially adapted for warming hospitals and infirmaries, as fresh air can be admitted direct into the air passages from the outside, and is heated before entering the room, and, being discharged in a vertical direction, no unpleasant draughts are experienced.

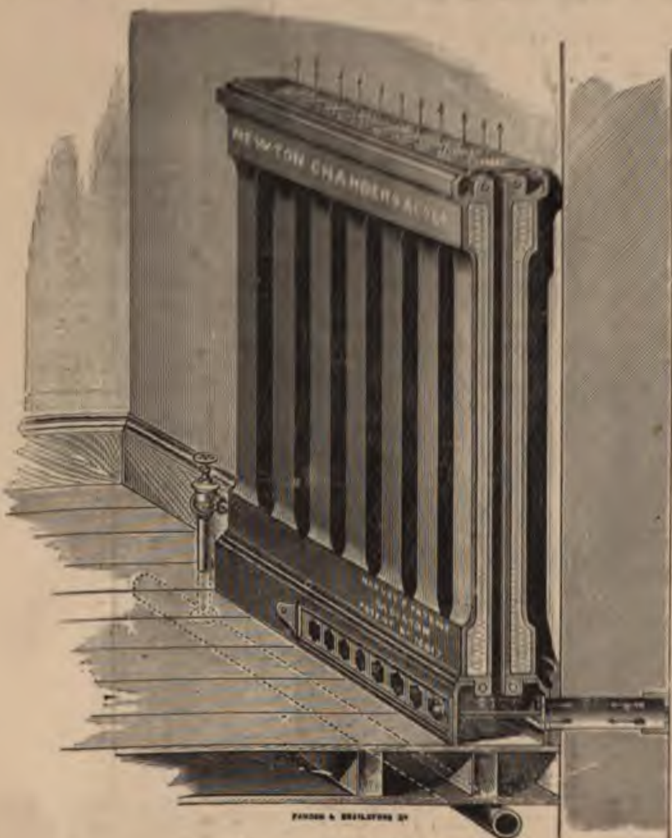

Fig. 1,728.

If a room is empty and the atmosphere not subject to vitiation, it may be maintained at an even temperature by circulating the air in at the base and out at the top of the radiator, without admitting external air.

No system of ventilation is complete that does not provide for the exit of foul air as well as for the admission of fresh air. The outlets should in all cases be greater in area than the inlets, and should be disposed so that the inlet air will sweep over the greatest space before it gains an outlet. In some cases the outlets are best near the floor, in others they are better near the ceiling; circumstances will always determine which is the best position.

Harvey's patent radiators are formed of vertical, single or double tubes. A single radiator is formed of tubes, each of which contains two waterways and one fresh air passage; a double radiator is formed of tubes, each of which contains four waterways and two fresh air passages. All the waterways are connected at top and bottom. The tubes are fastened together at top and bottom, so that there is equal contraction and expansion at each joint.

The tubes are fixed into a moulded base fitted with sliding ventilators at each side, to allow air from a room to mix with the cold fresh air, which can be admitted from the outside of a building, thus giving pure healthy heat.

The ventilators in base can be fitted so as to shut off the air from the outside and still admit the air from a room, or *vice versâ.*

The top is formed by a moulded cap with a [illegible] to allow the warm air, which comes [illegible]e, to pass into the room.

Heating Capacity.

A single tube is equal to 6⅔ lineal feet of 2 inch, 4½ lineal feet of 3 inch, 3⅓ lineal feet of 4 inch piping.

A double radiator twice the above heating power.

A radiator with gills on the tubes contains 1ft. 3in. of 4 inch piping per tube more heating surface.

A tube measures 2⅞in wide, and a radiator can be made any length up to 9 feet long.

Fig. 1,730 is a single tube radiator with air passage through the middle of the tubes, for quick heating. The air passes through the slide at the bottom, up the tubes, and out at the top, which can be regulated as desired.

Heating Houses by Steam.

Having seen Bailey's steam kettle, oven and hot plate, it will be easy to understand that houses, &c., can be warmed by steam. This is shown at Fig. 1,731. The warming pipes may be taken anywhere about the house, whilst at the same time, a good supply of hot water can be provided, as shown in the diagram. At the top of the house is a tank having a steam inlet and outlet pipe, this coil is surrounded by the water supplied by the small feed cistern on the left, with ball cock in the usual manner; and in this manner a good supply of hot water is kept up.

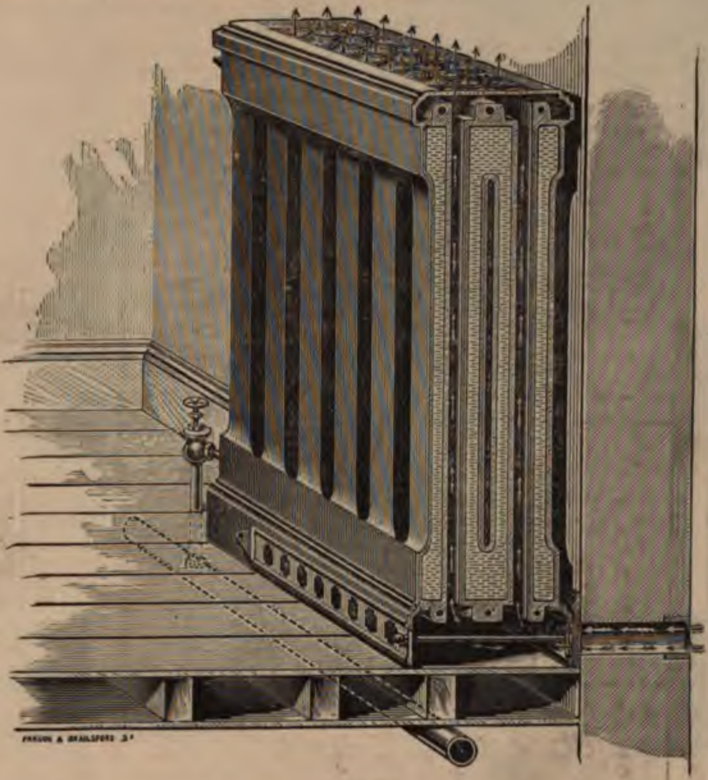

FIG. 1,729.

Warmth and Dust by Hot Water Pipe Heating.

Many of my brethren have noticed that in hot water pipe heating there is always a lot more dust than when heating by the ordinary open fireplace. When a room is heated by an open fireplace, the air is always more cold than when heated by hot water pipes, because the air is cooler than the things in the room, and the heat passes more readily through without heating the air itself. Rooms warmed by hot water pipes, the air itself gets the heat, and, therefore, warmer than the things in the room. Now, for the dust. When the air is warmer than the solid substances, it deposits its smoke, &c., upon the solids; but when the solids are warmer than the air, a current is set up, which keeps off the dust, except the larger or heavier particles, the weight of which overcomes the repulsion of the warm bodies. Here is a molecular bombardment or molecular impact at the surface, which defies dust particles lodging on hot bodies, but drives them to cold ones.

FIG. 1,730.

Boiler Statistics, or Hot Water and Steam Thermometers.

Fig. 1,732 is a handy instrument made by Messrs. Bailey, which may be screwed into any kind of pipe or boiler for registering heat.

This thermometer is indicated on one side of the scale in

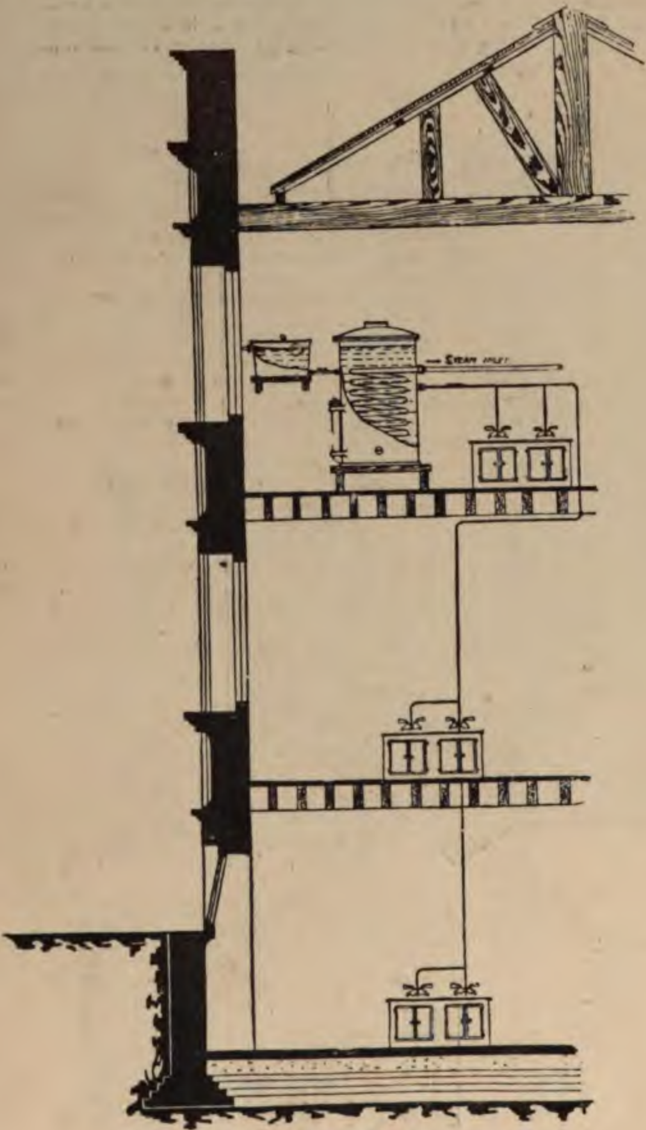

FIG. 1,731.

FIG. 1,732.

Fahr. degrees, and on the other in relative lbs. pressure. They have no stuffing boxes, the bulb being in a metal cistern, which is to be filled with mercury to bring the heat in metallic contact with the glass. This arrangement enables the tube and scale to be taken away, leaving the nipple in its place without breaking the joint, and the arrangement prevents the breakage of tubes so comm this class of thermometer. Originally designed for with Bailey's Stilwell heater, they have been adopte many other testing purposes where accuracy is desirab

You will see that this instrument answers as a the meter, and also as a pressure gauge.

EXAMINATION QUESTIONS.

COMMENT ON EXAMINATION QUESTIONS.

Here I have given a batch of questions for examinations. I have purposely refrained from giving the answers, as they will be best worked out by the students themselves, and I have made them as practical as possible without too much theory, and in such a manner that none but a practical workman, knowing well how to do the work, can possibly be the examiner, for we have had too much of this kind of examination already, much to the detriment of the really practical workman. I have seen examinations carried out by would-be examiners, who are nothing more nor less than rank outsiders, knowing, perhaps, how to wipe a joint, bend a bit of soil pipe, or boss up an angle, and assuming the dignity of the highest person in the land, which I consider to be a disgrace to the present plumbing trade in general. A man to be an examiner should be a first-class all-round plumber, who has worked in all classes of work, otherwise, how could he possibly become versed in the questions such as are now before you? Examination papers should be of a very varied class, so that the student should have a fair chance of answering questions which would come within his daily labour. The questions should also be plain, and without ambiguity. Many youths come from different parts to try their best in the language of their native place, and when they see figurative questions they are apt to become nervous, and once the mind gets into that state they cannot get along. Now, I have seen this occur scores of times, whilst another youth, of a pompous class, will not stick at anything, and more often by luck than judgment will come out of the trial with first-class honours, pushing himself into a position which he has never merited, whilst the quiet and secretly well versed plodder has to take a back seat. I know many who are second to none in this country standing in this position; in fact, some of these quiet and back-seated individuals do not know the depth of their own marvellous talent. I say marvellous talent from mixing with them. Get them into a quiet talking mood, away from all bustle and presumptuous individuals, and it is astounding what may be learnt from them unwittingly; whilst if you take the other class, you find that their marvellous amount of cheek, generally coincides with their ignorance, mixed up with downright bumptious conceit. Names are not to be mentioned, but I remember once, and not so long ago, there were some examination papers printed, which came into my hands for overhauling, or as some called it settling. The question was relative to the fixing of a jack pump. It said, "Give a description of a jack pump to draw water 28 perpendicular feet out of a well 30ft. deep, the suction to run horizontally ten yards to where the barrel is fixed, describing valves and bucket so as to work properly." This would make in all quite 30ft. perpendicular draught. When I saw the question I communicated with the author, who felt quite annoyed to think I should assume to approach his talents. I need not tell you that the question was not allowed to stand. Another one was, "Describe the process of casting sheet lead, the table, and the sand, and what necessary flux you will strew upon the sand to make the lead run freely." Again, I had to rap the would-be examiner's knuckles. The idea! "What necessary flux you will strew upon the sand?" This would have proved at once to the merest lad that ever assisted in sheet lead casting that the examination paper was a complete fraud.

No, this sort of examination and examiner is of no use to the plumbing trade; in fact, they are the very curse of the plumbing trade. Let the questions be from practice, and the examiners practical plumbers, then the thing will work. The plumbers, those that are plumbers in the true sense of the word, will admire the thing instead of treating it with disdain. For plumbers, again, those that are plumbers, of any lengthened experience, become thinkers, perhaps owing to the great variety of work which they are called upon to execute, and they know when the questions are practical. They also know what constitutes an examiner, and will admire a practical man.

Now, I will continue the explanation of the batch of questions, and give you a safe rule to success. First of all you must cut out a road, clearing all brambles and foreign rubbish away. Suppose you are going in to master, we will say, simple joint making: get first of all the theory that lead melts at a certain degree, then master the theory that tin with certain proportions of lead, melts at certain degrees below lead. Now, supposing you put this mixture, known as solder, on to your lead too hot, won't you be likely to melt your lead? Certainly, and you cannot work it (the solder) into a mass. Then, again, supposing your solder to be too cold, you cannot get it to move. The same also applies to the difference in the amounts comprising this composition of the two metals. If the solder is too fine it will work too fluidly, and cause the joint to appear scratchy, owing to the solder sticking on to the colder parts of the cloth. On the other hand, if it is too coarse, it sets too quickly, and appears like so much rotten-looking rubbish, not being able to keep up the heat, because the molecules of lead, when setting, tend, if disturbed, by a kind of trituration or disturbance to set into globular forms, which tin, in certain quantities, prevents—hence one reason for its use. Now having maste
points, it leads you into the nature and prop
material, and the practical part will be much e
but the practical part of the art is precisely
that gained by the thrower in the potteries,
smith's hammer man, viz., practice, practi
Now this is the way that you must work the
book, and then you will be able to not only
questions, but to give them, and this is what I a
wishing every apprentice plumber to be able to d

INDEX.

☞ All numbers refer to the paging except where it is distinctly printed "figure." Many of the titles in this index will be found under the ordinary headings, but many entries are also made in this index which have been taken from the middle or other portions of the paragraphs to save a multiplicity of headings; such will be notified by a star thus * before the page figures, and when the index refers to illustrations *only*, there will be two stars before the page figures thus **.

* See middle, &c., of Paragraphs (see Deads, page *18). ** See Illustrations only (see Urinals, self-acting, page **209).

* See middle, &c., of Paragraphs (see Deads, page *18). ** See Illustrations only (see Urinals, self-acting, page **209).

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...eads, page *18). ** See Illustrations only (see Urinals, self-acting, page **209).

INDEX OF SURNAMES IN THIS VOLUME.

* See middle, &c., of Paragraphs (see Deads, page *15). ** See Illustrations only (see Urinals, self-acting, page **209).

GLOSSARY OF OBSOLETE AND TRADE WORDS,

ALSO OF WORDS VARYING FROM THEIR ORDINARY SIGNIFICATION, AND TRADE TERMS GENERALLY.

About right. A job done well.
Accumulator plate. A leaden plate of a spongy nature, or having ribs or grooves for storing electricity in a secondary or storage battery.
A 1, copper bottom. A first-class workman.
A coil. 30ft. of 1¼in. or 1½in. and 2in. lead pipe.
A coil. 60ft. of ½in., ¾in., or 1in. lead pipe.
Acres. A plumber afraid to tackle a job; a coward.
After flush. A flush of water to run after you leave go a closet pull or handle, so as to charge the basin of a valve closet.
Air chamber. A vessel wherein air is imprisoned to form a cushion for the water, so as to prevent jars, and to give a continuous stream.
A length ... in lead pipes. (See Length.)
All-...
... astonishing story.
... to fix work

Artesian wells. Formerly wells bored by mechanics through impervious material till water was found at Artois, in France, where well-boring was supposed first to be done, but which is not correct, the Chinese having a much longer record of such work.
Asphyxiator. An apparatus for generating smoke for testing drains, &c.
Astragal. A bead and fillets, forming a small moulding.
Atmospheric pump (same as Jack pump).
Aunt, my. A water-closet.

Bacillus (see Cholera bacillus).
Bags. Trousers. Plumbers for 300 years wore large trousers, and from about 1850 to 1870 wore them so large and straight-legged, which entirely hid the toes of the boots, that the people used to ask them if they carried their tools in their trouser legs. Hence the name "Bags" for trousers. Shakespeare called them "...umbags."
...er. A lever having a ball at the end to balance ..., used in connection with the wires of a w... ... to a water-closet.

Ball valve. A faucet governed by a valve, a kind of ball cock.

Barn-shaped. Leaden traps made excessively larger than is necessary to be self-cleansing, or other such unproportioned manufactured goods.

Bar solder. Plumbers' solder, somewhat of a triangular shape, the section across the bars being the shape ▽, the bars about 12in. to 15in. long.

Barreling. In pump work large strong leaden piping used in deep wells where stuffing boxes, &c., are objected to, and in places where the well or working barrel is not easily got at for repairing sucker box.

Barrels. In pump work the cylinder wherein the bucket or piston works.

Beaver. Beer or ale about 10 or 11 A.M.

Bester (same as Marpot).

Bird's eye. A hole made in lead by a bad workman.

Bit. A solder iron made of copper, with iron stem and wood handle.

Blead, to. To blead signifies to make a small round bradawl hole in a pipe to get dead water out for patching pipes. The hole is then closed, sometimes with a wooden peg driven home and soldered over with a copper bit.

Blocks. Two blocks of 4½in. by 3in. quartering, 3in. thick, having a quarter circular portion cut out to receive soil pipe when it is being prepared on the bench or floor.

Blue or bluey. Lead.

Blue pigeon-flyer. A person who makes away with lead illegally.

Bluey cracking. Breaking into a house and stealing lead therefrom.

Bobbin. An elongated kind of hard wood ball or drift used in pipe bending to keep it round; it is driven through the pipe with drifts, which see.

Bocland. Bookland.

Bolt (see Tommy).

Boss. A brass ferrule, wherein screws a cock or draw-off valve.

Bosser. A plumber.

Bossing. To boss up. To work up a corner of a leaden gutter, tray, cesspool, or a brake so as to do without solder or burning.

Bossing iron. A square-nosed iron for heating the boss when cementing in.

Brake. An internal angle from the outer side of a leaden gutter.

Brass me up. A vulgar way of asking for wages when leaving an employer in a huff.

Breeched. To be in good circumstances.

Breeching. The junction or rounded part of lead burning cocks.

Britch. To britch. Ask an old plumber.

Broil. The end of a galena vein.

Bucket. A term in pumps. The working part or piston, having a valve in the centre.

Butt. A water vessel in the shape of a barrel having one head or end out.

Calme, or carm. Window lead.

Captain. The agent under the purser in lead diggings.

Carucate. As much land as can be ploughed with one plough in twelve months.

Caulk. To run lead into a socket, &c., and then drive it in with a blunt chisel to compress it, to prevent leakages.

Caulker. A marvellous story or lie.

ulker (see Jointer).

spool. An underground catch pit for receiving sces and slops generally. Also a leaden box to ceive the rain water from leaden gutters.

Chalk water beds. Same as oolite beds, which see.

Chalybeate. Charley Bates, water charged with iron.

Chambers. In lead mining tunnels.

Chambers. In lead pumps called air chambers.

Chambers. In vitriol works closed places like la leaden tanks to condense sulphurous fumes.

Charley Bates. Water charged with iron which so corrodes the solder in leaden cisterns; burnt cister are not affected with this.

Choker. A downright lie.

Cholera bacillus. A kind of deadly microbe that flo in the air and water, and so small that it would ta fully 12,000 to form a thread or procession 1in. long

Cistern pump. A pump having an air-chamber bel the pump bucket.

City solder. Two of lead and one of tin, stamped wi the Plumbers' Company's stamp, a very old custo but now beware of solder stamped "City Solde as it is stamped this name by makers without t arms stamped thereon, as it should be by the Plumbe Company.

Clack. Part of a valve, generally the top part.

Claw. A kind of grapple iron, used to support the ro etc., in well boring.

Cloth, plumbers', for joint wiping. A kind of pad ma of moleskin, made to a suitable thickness by usi one layer over another till thick enough to preve the solder burning the hands.

Clout. A countersunk headed nail.

Clove of lead. In Henry VI.'s time, 7lbs.; Edward I 8lbs.

Coach. A little trolley having an iron pan on top to r the surplus lead from the sheet lead casting bed to t melting pot.

Coburg. A short length of ¾in. or 1in. cast lead pi with a flange cast thereon for connecting the lead mains to the street mains used thirty years ago.

Cock (ground-in). Same as Plug tap.

Cock (screw-down). A valve, cock, or tap for sinks.

Cockeys. Plug cock makers.

Cock's eye (same as Bird's eye).

Continuous primed pump. A pump constructed s to get empty should the valves leak.

Copper bolt (see Bit). The name is taken from sh plumbers making solder irons from the copper bol used in wooden ships.

Copperish. With plumbers when the landlady charg too much for grub and diggings.

Costeaning. Boring or digging holes at right angl for galena.

Councillor. A plumber's helpmate or apprentice.

Crab. When being wound up or down a well to l knocked against the staging, &c.

Cram. To put a piece of wood, &c., into the end of seam roll when working down the end

Cramming, or stop back. To cram a pipe with so bread worked into a firm ball or roll, and pushed int a pipe where a cock or valve lets by slowly, so that joint can be made; sometimes whiting or clay i used instead of bread.

Crane. A draw-off water cock, tap, or valve.

Curb. In wells a wooden drum without heads.

Deads. Foreign rubbish, associated with galena mineral ore.

Devil. A plumber's fire-pot.

Diggings. A lodging or apartments wh away from home.

Dip pot. A pot for dipping the point when cutting up sheet lead.

Distant pump. A pump worked a pump at a distance.

Document, the (see Ticket).
Dog-earing. Turning the corners of lead in a fold so as to make a tray without bossing, burning, or soldering up the angles; pig-lugging.
Dog wrench. A tool for unscrewing pump screws at any angle, and for confined places.
Dolly or sam shop. An illegal pawnshop, or a place where stolen articles are received. This name is taken from the sign of the black doll, once the sign of a rag-shop.
Down pipe. The supply pipe to a water-closet.
Dresser. A wooden tool with handle for flattening dents in sheet lead, or for angling up sheet lead.
Drift. A kind of short mandril to drive the bobbins through pipes to get the dents out.
Drip. The junction, and where two gutters meet one emptying into the other; the outlet of a gutter if turned down.
Drip tray. A tray made of lead to catch the drippings of sulphuric acid from the top of an acid chamber; a pipe conveys the acid to the external part of the chamber to show the rate of condensation.
Dripping box. A leaden cesspool on a roof.
Drop (of cold water). Taken to weigh one grain.
D trap. A stink trap made in the shape of the consonant D, a trap extremely abused by those not knowing its qualifications, and by people interested in other makes of traps, also through inferior workmanship, bad flushing, and bad ventilation.
Duffer. In plumbing, a bad workman.
Dummies. A tool made with lead having a wooden or iron handle sometimes bent for pipe bending.
Dummy. A piece of cane with lead on one end, used to knock bruises, &c., out of soil pipes, and used for bending soil pipes.
Dutch auction. A lease of a lead mine to three or five lead miners for six months.

Ears (see Tacks).

Ferrule. A union or other brass connection whereby the leaden pipes are connected to the street mains.
Figure. What is the figure? Wages per hour. Same as Screw.
Finger pipe. A blowpipe for lead burning.
Flange joint (same as Taft).
Flapper. A flat piece of lead used to knock sheet lead smooth or into certain places to find the members of a mould, such as a moulding on a rain-water head, &c.
Flask. A kind of frame to hold sand for lead casting (not for sheet lead).
Floating pole. In pump work a wooden pole whereon the bucket is fixed. This works lighter on the hand than a long length of iron pump rod.
Fluckans. Slate or clay in a lead mine.
Flummuxed. The whole job spoilt.
Fodder of lead. In London, 19½ cwt.; in the North, 21 cwt.
Frame. A sheet-lead casting table.
Frame pump. A wheel pump whose frame can be used for winding men up or down in deep wells, often working with cogs and wheels, and called "geared" pumps.
Funnel (same as Soil pipe).

Galena. The proper name for lead ore.
[illegible]gue. A word derived [illegible]an *gang* (or "vein"), [illegible]stone.
[illegible] (see Fr[illegible]
[illegible] a [illegible] [illegible]fter the joint [illegible]eating.

Gone to smash. Bankrupt.
Graft. Work. "Are you in graft?" signifying, "Are you in work?"
Gram. Taken to equal 15·438 grains. (See Drop.)
Grass. On the surface above a lead mine.
Grass captains. The underground men in a lead mine and next man to the captain.
Grub. Food supplied at your lodgings, &c.

Hachet bit. A copper bit in the shape of a small hatchet.
Half S. An S trap with one quarter cut off.
Hand dressing. Sorting galena from rubbish with sieves by hand; in water, sometimes called "standing buddle."
Hards. Old joints cut from old and other lead pipes, &c.
Hearth. The bed of a muffle. (See Muffle.)
Heat. The proper heat for the metal, or solder working; also used in lead casting: "Is the heat up?" or "Have you got the heat up?"
Hide. 120 acres.
Hoisting board (see Stage).
Horse. In casting, a beam or piece of timber to carry a mould for mould-making; in sheet-lead working, a mould to dress lead into shape, such as finial bases.
Hump. A plumber out of temper with his work; ill-tempered, like a cat with its back up.

Inside work. Fixing pipes, &c., inside houses, &c. Even fixing soil pipes outside a building is called inside work.
Irony. In water, chalybeate water.

Jack pump. A leaden pump made to pump water out of shallow wells; a suction pump.
Jaw box (see Iron sink). So named on account of washerwomen's jaw when at work.
Joint, plumber's. A joint made with solder, wiped smooth and clean, with good shape, and symmetrical.
Jointer. A man who makes the joints on cast-iron water and gas mains. He is also called a caulker.

Killed spirits (see Spirits).
Knighted. A pin put into the key of a cock so that the key will only turn quarter way. Used in ball cocks.
Knocking off stick lead (same as Little man).
Know-all. One who knows everything and yet knows nothing.

Ladkin, or ladakin. A glazier's tool for opening the calmes of window lead.
Languet. An iron fork on a pump rod made to work the bucket when the bucket is a short one. Very old.
Lead burning. Jointing the edges of lead by use of an aerohydric blowpipe, whereby these edges become one homogeneous mass of lead, and without the use of solder. The best of all joints for lead work, and especially so for chemical works; or, tanks containing acid, or chalybeate water.
Lead laying. Fixing and working lead on roofs.
Lengths of lead pipe. ½in., ¾in., 1in., equals 15ft; 1¼in., 1½in., 2in., equals 12ft.; 2½in., 3in., 3½in., 4in., and upwards, equals 10ft.
Liquation. Refining tin.
Little man. A piece of plasterers' wood lath, sharpened to a point, to knock off all surplus lead when drawing leaden soil pipes with solder and irons.
Lode. The fissure or crack in the strata or a vein of galena, sometimes found at the surface, which may run miles under ground and up again, when it is known as "broil," or "done with."
Lushington, a. A drunkard, or one who continually soaks himself with beer.

Machine, lead burning. A kind of enclosed box of lead for generating hydrogen gas (see Lead burning).
Mandril. A smooth wooden parallel pole to bend sheet lead round for making pipes thereon.
Marpot, a. A bester, or one that is two-faced or mean, and will crawl into another's shoes by slyly edging a good man out of his position or "graft"; a sly cuss.
Massicot. Lead dross.
Mate (same as Councillor).
Metal. Plumbers' solder.
Microbe. A minute germ, many classes of which are pathogenic to man, whilst other classes are not so.
Mid-feathers hollow. Flanges on boilers which partially form the flue.
Mignonette bed. A privy.
Mineral trail. To trace galena in the earth.
Miser. A kind of auger used in well boring.
Mizzle off, to. Other workmen making a duffer resign his job, or to "take his hook" off the job.
Monkey. A dead weight used in connection with pulleys to drive tubes in tube well work.
Mooch. A moocher; a fellow nearly always out of work, also a fellow nearly always looking for things that he can turn to a profitable account; to slink away from a job half done, and which will not stand a test.
Muffle. A reverberatory furnace.
Mulled over. Work attempted but spoilt, or good work spoilt by an inferior workman meddling with it.
Mully. A kind of loam used in cock grinding.

Nicking buddle. Like running buddle, but with the trough made like a cross, where the ore is put and mixed with plenty of water in the head trough. The water is then allowed to run down the bottom cross to collect any galena which is not deposited in the top trough.
Nidus. A covering of a network character.
Nipples. Lead burners' jets.

Oolites. Beds of sand and gravel which soak up and hold water sponge-like, and again yield it by degrees; a water-bearing kind of strata like that of chalk beds.
Outgo. The outlet of a stink trap.
Out of draught. A suction pump fixed too far away from the level of the water in a well, whereby the atmospheric air cannot force the water into the pump barrel, or as plumbers say, "The pump won't suck it up."
Overcasting, or glazing joints. The act of rubbing the hot iron over a joint just after it has been made. This is to seal over the pores of the solder to prevent the water, &c., sweating through. Especially used on suctions of pumps.

Pair of plumbers. A plumber and labourer.
Pan closet. A closet having a container or large vessel wherein works a copper bowl or pan to hold about three pints or so of water, and was introduced about sixty years ago as a substitute for the valve closet.
Pathogenic. Inoculation of disease.
Peg-into-it. To go to work with a will of doing a lot of work; to work hard.
Perambulator. A frame on which wooden pumps are bored.
Pigeon. Lead which flys away from roofs, or loses in transit.
Pig-lugging (see Dog-earing).
Pilches. Lead mine divided out to grass captains, size varies from 60ft. high by 33ft. long.
Pin (same as Tommy).
Plug tap. A cock having a shell and ground-in plug.
Points. Small chase wedges used for gutter drips, &c.
Poling boards. Boards about 2ft. or 3ft. long used at the back of walings in drainage work.
Poney. Ask an old plumber; also used in well work as a safety when being wound up or down.
Pot. A lead melting pot set in brickwork. This name is religiously used by lead casters, and should any one call it a copper, it means 2/6 fine.
Potato trap. A careless speaking or speaker's mouth taken from *Hibernicism*. A word of contempt for a chatterer.
Pouring stick. A stick about 12in. long, 1½in. wide, ¾in. thick, with a hollow cut on one side to pour solder into when the point of the stick is directed to convey solder to any place where a splash stick cannot be used. Also used for soldering the upright angles of cisterns.
Priming pumps. Throwing a pail of water into the barrel to cause the bucket to draw or suck.
Privy. A closet of decency, usually made where water-closets cannot be constructed.
Pros. A water-closet; abbreviated form of *πρός τινα τόπον* (Oxford University).
P trap. Nearly the same as a D trap, but with the outlet square and open, and more of a P shape.
Pump tree. A tree bored to form the barreling of wooden pumps.
Purser. The head business man in a lead digging.

Quench hook. A piece of ½in. round iron having a 1¼in. eye or hole at one end and a pot hook at the other so as to quench the handles of the plumbers' irons and carry the metal pot.
Quench pail. A pail to cool the handles of plumbers' irons.

Race. The shute which conveys water to an overshot water wheel.
Ram. Hydraulic ram taken from the long trunk of water which rocks and drives, similar to the battering-ram.
Ramshackled. Knocked about, shattered; old fittings, such as old water-closets, old water mains, &c.
Regulators, various (see Acid-making and Lead-burning, Water Closets, &c.).
Rigg. To rig a pump; to fit up a pump with all necessary fittings and working power.
Rings. In cock grinding; the scratches, &c., when the grinding material is too coarse and too dry.
Ripper. A roof tool for taking the nails out of slates when fixed.
Roaking, roke. To go where you have no right or where you are not wanted; to rummage; near to the word "grope," except darkness.
Roasting. Smelting galena in a muffle or reverberatory furnace.
Rocking standard. A movable fulcrum for the lever of a pump handle.
Rod and sling. A contrivance for making pump rods work through a fixed socket; to keep the rod perpendicular and to form a rocking motion, or for a similar use to that of the vibrating lever, but not so good for deep wells.
Rolling joints. The act of moving or rolling the pipe and joint in a circular direction that the hand and cloth can remain on top so that the joint may be round; a bad practice.
Roll of lead. 7ft. by 30ft., or larger.
Rotherham screw-down. The ordinary screw-down draw-off cock or valve, so named from being first made at Rotherham.
Rotten. Porous lead, sometimes called spongy.
Round valve. An old water-closet valve leathered and having a knife-edged seating. The valve is weighted down with lead.

...ners. Perpendicular planks driven into the earth in ...aking drain work, &c.

...ning buddle. Washing lead ore in troughs having a good supply of running water.

...k. To get the sack; to be discharged by an employer.

...dle. In well work a piece of wood with a rope end through, having a knot tied thereon, and whereon you sit straddled whilst going down or coming up a deep well.

...fe. A tray to catch overflows or leakages, used under water-closets, baths, cisterns, &c.

...nt Monday. When a workman, especially a mechanic, takes a holiday on Monday it is called Saint Monday.

...m. To stand sam; to pay for refreshments or the drink of others. (See Dolly shop.)

...turn or lead glance. Sulphuret of lead and the ancient name of lead.

...amp. To give work the go-by; to do it badly and without due consideration.

...raping castle. A water-closet.

...rew. A plumber's or labourer's wages. (See Figure.)

...rvice box. A leadon box to supply an after-flush to a water-closet.

...t-offs. Two bends in a pipe to alter a line of piping, such as a bent pipe to go over a plinth.

...etting knife. A glazier's knife for cutting calmes of window lead, having a bone handle, which also acts as a hammer to knock up the panes of glass into their place.

Shady. Getting past the age of work; also to do an act not quite straightforward.

Shaving. The act of cutting a minute shaving off the lead where you wish the solder to adhere.

Shed-a-tear. To drink with workmen; a glass together before parting for home at night; a kind of pathetic phrase with plumbers at parting.

Shells. The two parts forming water balls.

Shoaling, or exploring. Searching for galena.

Shoddy. Bad and cheap work.

Shoe. In pump work the iron which is fixed in the steining for the stages to rest on.

Shoe valve. An old valve for water-closet work, not yet improved upon, though tens of thousands have tried to.

Sixes and sevens. Work in thorough confusion, began upside down, anyhow.

Skuller. A man that is careless and drops anything down a well on a plumber. (The smallest bit of stone falls dreadfully hard in deep wells.)

Slacker. A mallet or hammer.

Slats. Ash lagging for going round lead burning machines.

Slogger. A hard worker; generally not very particular as to how the work is done so that it is sound.

Smudge (same as Tarnish).

Snack. A little food, such as a bit of bread and cheese with a pint of beer at beer time.

Snap. The pulling and letting go of a chalk line.

Soil (same as Tarnish).

Soil pipe. The leaden pipe leading from a water-closet trap to the drain.

Spirit brush. A brush made with 6in. of ¼in. compo ...nd a few bristles about ⅜in. long, the pipe being ... with a blow from the hammer to hold the ...

...oric acid or spirits of salts, also killed ... as much zinc in as the spirits of ...

... the ladle on

Splash stick. A bit of wood lath 6in. long, ½in. to ¼in. thick, 1½in. wide, used for spitting or splashing.

Split bends. Leaden bends made in two halves.

Spongy (see Rotten).

Springing beam. The pole or timber which lifts and supports the augers, chisels, rods, &c., in well-boring, sometimes called a jigger.

Spring valve (very old). Similar in shape to the shoe valve, but closing below, and by means of a spring fixed on a spring board on top of the cistern.

Stage. In pump work, the foundation whereon the barrels and pipes are fixed in deep wells.

Stage, board, or frame. A large board to unroll your lead upon when fixing the sides of acid and other chambers.

Standing buddle (see Hand dressing).

Stand post. An iron post whereto is fitted or fixed a draw-off for drawing water.

Stand post plug. A portable kind of stand post, having one end prepared to attach to the fire hydrant or fire plug hole.

Staves. These are like slating battens, or slats for lagging round pipes when supported overhead, or for suspending very large pipes.

Stem nail. A kind of brass or gun-metal countersunk headed nail, about 2in. to 3in. long, ¼in. or so thick, flat or chisel-pointed, used in chamber work.

Stick lead. Lead run into sticks 15in. long, of a triangular or even square shape, and about ½in. thick.

Stinking germ water. Water full of eggs or germs capable of giving contagious disease, or water containing germs, which under favourable conditions multiply 16,500,000 separate germs within twenty-four hours.

Stink trap. A water lute or apparatus holding a certain quantity of water or other liquid wherein a pipe dips or a diaphragm is used to prevent noxious gaseous vapours readily passing through the pipe without getting through the liquid.

Stoney. Bankrupt; a workman without cash.

Stop back (see Cramming).

S trap. A kind of round way stink trap taking the form of the consonant S laid ∽.

Strap solder. Solder run into strips ½in. to 1in. wide, ⅛in. thick, and 12in. to 18in. long.

Stuff. In plumbing, the lead and materials, such as is the stuff on the job.

Sucker box. The lower valve of a jack pump.

Suction pipe. A pipe dipping in such a manner that water and air are held in the pipe.

Suction pump (see Jack pump).

Sweater. A master that requires more work done than is good for the workman's health.

Sweating. A leakage coming through the pores of the solder or other material like beads of perspiration from the brow of a man.

Sweating. In coarse solder work first you form welted joints, then splash some coarse solder on them till the joint will take no more; then quickly wipe all solder away and rub the joint flat with the dresser, so that the joint will be flat and quite tight together.

Sweating in joint making is when secret joints are required; you make the joint so that it cannot be seen; at other times copper bitting a boss or other brass work to lead, &c.

Swedge. A groove or recess in the shells of copper water balls.

Swob. A sponge.

Swobber. A plumber's mate or labourer trained to keep, with water and a sponge, the pipe from opening when drawing lead pipes.

Swob pot. A hand bowl.

Syphon. In drainage work, a stink trap, which see.

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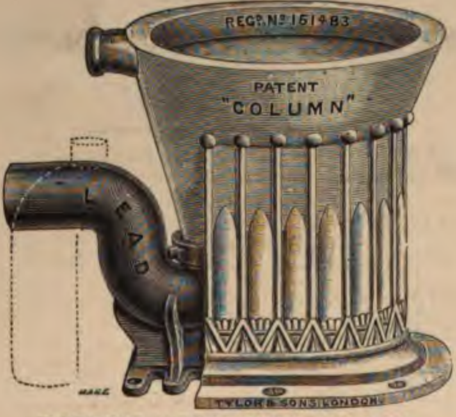

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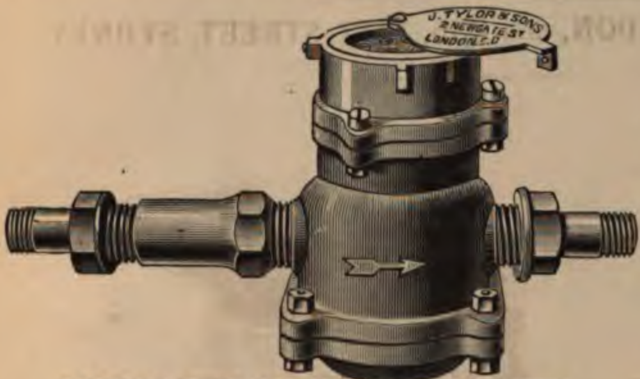

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Mr. JOHN BLAKE,
Estate Office, Eanam Brewery, Blackburn, October 29th, 1895.

DEAR SIR,—In May, 1894, you fixed at Woodfold Park, the residence of R. A. Yerburgh, Esq., M.P., a pair of your Patent "B" Rams, with about half-a-mile of delivery pipe and cast-iron main with valves and plugs for fire extinguishing. The Rams are worked by river water, and you promised that they would force 7,000 gallons of spring water per day of 24 hours, to the reservoir, at an elevation of 178 feet 9 inches above the Rams.

I have great pleasure in saying the Rams have proved capable of doing more than you promised, they have worked and are now working exceedingly well, and are easily managed by a man on the estate who had no previous experience in Rams. I think the materials and workmanship do you much credit.—Yours truly,

JOHN HOWSON, Estate Agent.

From T. FERNYHOUGH, Esq., Agent to the RIGHT HON. LORD HINDLIP, Bradley, Ashbourne, Derby, March 17th, 1894.

DEAR SIR,—Referring to the two Patent "**B**" Rams you started six months ago for the Right Hon. Lord Hindlip, on the Alsop-en-le-Dale Estate, I am glad to congratulate you on the success of your attempt to raise the necessary supply of water under conditions so difficult, the height to raise the water being more than **sixty-three times that of the working fall.** The Rams are worked by water from the River Dove, with the small working **fall of 8 feet 3 inches,** and issuing from the rocky bank close by is a copious stream of pure spring water, **8,000** gallons per day of which the Rams force to a reservoir three-quarters of a mile distant, and at the extraordinary height of **532½** feet above the Rams. The water is then gravitated from the reservoir to the several farms and houses on the estate, giving an ample supply to each, and still leaving a good overflow at the reservoir.

I am glad to add that the Rams lift more water than you promised, and seem to work with great ease and smoothness, notwithstanding the great elevation they force to.—Yours faithfully,

T. FERNYHOUGH.

From The RIGHT HON. THE EARL OF HARROWBY, 44, Grosvenor Square, London, February 21st, 1893.

SIR,—I have pleasure in stating that the two Hydraulic Rams which you supplied and fixed for me last autumn, at Sandon, have proved so far most successful, and that the work gives every promise of durability, while the economy, compared with the former much smaller and intermittent supply by steam pump, will be considerable.

With a fall of about 14 feet from a previously existing mill-pool, the Rams supply reservoirs 168 feet above the brook whence the water is forced, through pipes 1½ miles in length. They sent up, as long as I required it, about 41,000 gallons per day. I now generally work the two Rams alternately (for a fortnight or so each), but can at any time work the two together, if the full supply of 41,000 gallons should be needed.

The business of this somewhat complicated water supply was conducted by you with singular promptness and punctuality; and no local difficulties arose in the execution of the work, owing to the excellent and efficient men whom you sent from your works at Accrington.—I am, Sir, your very obedient Servant,

HARROWBY.

From MARTIN CURTLER, Esq., Agent to the RIGHT HON. LADY NORTHWICK, Sansome Place, Worcester, February 18th, 1895.

DEAR SIR,—I have great pleasure in informing you that the Hydraulic Ram which you put in for the Right Hon. Lady Northwick, at Northwick Park, last year, has worked, and is working, most satisfactorily. The water, as you know, had to be raised to the height ...rly 400 feet, with 1,900 yards of rising main pipe, to a large ... top of a hill ... to supply several farms on the water by

The supply to the tank is most ample, and there is an adequate overflow left below the Ram. Altogether the work is a very great success.—Yours faithfully,

MARTIN CURTLER.

From J. B. McCALLUM, Esq., C.E., Borough and Water Engineer, Blackburn, November 1st, 1886. Guide (Borough of Blackburn) Water Supply.

DEAR SIR,—Following is the short report I promised to send as to the work performed by the Hydraulic Rams—supplied by you to the Blackburn Corporation—after they had been in operation sufficient time to take proper observations.

The district of Guide—population about 500—in the Borough of Blackburn, is situated above the highest reservoir of the Blackburn Waterworks, and had no regular water supply until last July, when the Water Committee caused two of your Patent Hydraulic Rams to be put down and worked by water from a reservoir having a varying but maximum head of 34 feet 3 inches on the Rams—the waste (clean) water gravitating to a lower adjacent reservoir.

You contracted to supply Rams which would force 8,000 gallons per day each through 1,295 yards of delivery pipe to a service tank 170 feet above the Rams, and I am bound to state that the result has considerably exceeded my expectations, as the Rams are capable of pumping, and have pumped, much more water than you promised. The percentage of efficiency exceeds all I expected, and is, in my opinion, much more than is usually obtained from Hydraulic Rams.

From a test I made on September 29th, I found that two Rams with ¼ inch and ⅜ inch strokes respectively, supplied with 194,030 gallons per day, together pumped 26,090 gallons per day to a height of 170 feet, giving 71·43 per cent. of efficiency, and one Ram working at ⅜ inch stroke, and with only 16 feet of working fall, supplied with 154,587 gallons per day, pumped 10,587 gallons per day to the same height, showing 72·75 per cent. of efficiency.

At a subsequent test on October 11th, one Ram at ⅜ inch stroke, and having 31 feet 9 inches of working fall, supplied with 121,083 gallons per day, pumped 17,583 gallons per day to an elevation of 171¼ feet, the efficiency in this case being 79·57 per cent.

In arriving at these results the greatest care was taken to positively measure the water, besides having a meter check on feed and delivery pipes.

The work carried out by you at Blackburn is substantial and satisfactory in every way, and if any engineer wishes to make his own observations he is at liberty to come here and do so.

From T. DYNE STEEL, Esq., M.Inst.C.E., Past President South Wales Institute of Engineers, Bank Chambers, Newport, Mon., April 24th, 1891.

USK WATERWORKS.

DEAR SIR,—In September of last year I applied to you for a Hydraulic Ram for the purposes of the Usk Waterworks, to be capable of raising 27,000 gallons per day, a height of 127 feet, with a working fall of driving water of 27 feet, and on your guaranteeing that performance, I gave you an order for the Ram. The machine you supplied has now been put to work, and I have much satisfaction in saying that it far and away exceeds in its performance my most sanguine expectations, and possibly yours also. I have just completed a series of exhaustive tests, with the following results:—Working fall of driving water, 30 feet; vertical height raised, 127 feet; length of rising main, 850 feet, from Ram to outflow; length of supply pipe, 200 feet; gallons per hour raised, 1,612; driving water used per hour, 8,186 gallons, showing the remarkable and gratifying result of **83 per cent. of efficiency.** The tests were carefully made and repeated, the water measured and levels properly taken. Several trials were made, and I shall be glad to give any engineer interested in the subject facilities for repeating the tests at the spot. I may here state that for the rising main I used a large diameter of pipe, in order to reduce friction, with excellent effect.—Yours faithfully,

T. DYNE STEEL.

...ord Street Works, ACCRINGTON, LANCS.

ESTABLISHED 1790.

JAS. WOODWARD & ROWLEY,

SWADLINCOTE, near Burton-on-Trent,

Sanitary Potters.

TELEGRAMS TO "ROWLEY, SWADLINCOTE."

Sole Manufacturers of the "WASH-OUT" CLOSET (Patent).

Patented and Registered "**ESSER**" Lavatory, No. 1,927.

(For full particulars apply as above.)

... CLOSET TRAPS, URINALS, LAVATORIES, SINKS, AND OTHER SANITARY FITTINGS.

...TS AND FULL PARTICULARS ON APPLICATION.

CRAIG'S NEW UNDULATED FRONT LAVATORY.

Registered No. 244,555.

ALL KINDS OF SANITARY EARTHENWARE.

No. 67.—Size, 27 in. by 19¼ in.; Basin, 20 in. by 13 in.

GLAZED WALL TILES, White, Tinted, and Enamelled.

THE "NYPHOS" PATENT SYPHONIC WASH-DOWN CLOSET AND CISTERN.

CRAIG'S PATENT ENAMELLED FIRE-CLAY SYPHONIC CISTERN.

CRAIG'S "MILLION" WASH-DOWN CLOSET, in finest Earthenware—White or Ivory.

BUCHAN'S PATENT GREASE TRAPS, ACCESS PIPES, &c.

ENLARGED OPENING ON TOP.

No. 130.

BUCHAN'S PATENT IMPROVED VENTILATING DRAIN TRAPS, WITH ENLARGED OPENING ON TOP.

Latest Patented Patterns.

(Prices same as for ordinary Patterns.)

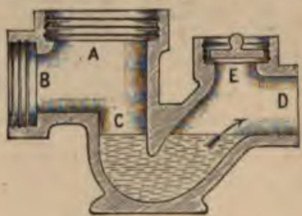
WITH MOVABLE HEAD.

No. 134.

EXTRACT FROM TESTIMONIALS.

W. KAYE PARRY, Esq., M.A., B.E., M.Inst.C.E.I., F.R.I.A.I., Architect, Dublin, writes :— *Jan. 8th*, 1894.

"I have much pleasure in stating that I have had a great deal of experience in the use of the new pattern Buchan Trap, with the enlarged round opening on top for ventilation, inspection, and cleansing. I consider this Trap the best of its kind in the market. Where expense is a consideration, and manhole chambers cannot therefore be constructed, the large opening affords considerable facilities for access to the Trap for inspection. It is also very useful for ventilation. I have specified this Trap in a large number of instances, and with uniform success."



No. 133.

WITH EXTRA SIDE INLET AT RIGHT ANGLE.

No. 136.
Right hand. (May also be had left hand.)

Stock Sizes of Wide-headed Traps.

Inlet. B	Outlet. D	Opening at Top below Faucet. A	At Well. C
4 in.	4 in.	9 in.	4 in.
6 in.	6 in.	9 in.	5 in.
9 in.	9 in.	9 in.	7 in.

ABOUT 120,000 BUCHAN'S TRAPS HAVE BEEN SOLD.

WITH EXTRA SIDE INLET AT ACUTE ANGLE.

No. 139.
Right hand. (May also be had left hand.)

Sole Makers: J. & M. CRAIG, KILMARNOCK.

SHANKS & Co.,

TUBAL WORKS, BARRHEAD, near GLASGOW,

AND AT

LONDON, MANCHESTER, DUBLIN, GLASGOW, &c.,

Patentees and Manufacturers of

HIGH-CLASS BATHS, LAVATORIES, WATER-CLOSETS, LATRINES, WATER WASTE PREVENTERS, URINALS, SINKS,

And Sanitary Appliances and Fittings of every description.

SHANKS'S NEW PATENT "BARRHEAD" SIPHONIC CLOSET

Effectually solves the long-vexed Siphonic Closet Problem.

Results obtained are TRULY MARVELLOUS. Supersedes anything yet brought out.

This phenomenal Closet possesses the following advantages:—

It is the Simplest in Construction.

It has the Deepest Seal. (8 inches.)

It has the Largest Surface of Water of any Closet. (13½ by 11¼ inches.)

It is the Most Perfectly Flushed.

It has the Most Powerful Discharge of any Closet.

It requires only -Gallon rn.

It cannot go out of Order.

It cannot be Unsealed by throwing in Slops.

It has no Second Trap.

It has no Joints on Drain Side of Trap.

Fitted with "Perfecto" Seat for Greater Cleanliness.

No connection with Wall.

Illustrated Sheets of this Closet can be had on application.

ated Epitome" of Patented Sanitary Appliances having and, copies can now be had on being written for.

A. EMANUEL & SONS, Limite

SANITARY ENGINEERS,

9, 11 & 13, GEORGE STREET, MANCHESTER SQUARE, LONDO

THE "METEOR" WASH-DOWN CLOSET

(REGISTERED),

WITH PATENT CAST LEAD TRAP AND SEATING

Side View with fixed Slop Top.

Side View with section of Trap.

THE above has been designed to meet the ever-increasing demand for Pedestal and other Closets *with Lead Traps, to which Lead Soil Pipe may be connected by means of a Plumber's Wipe Joint.*

It is made with S Trap and P Trap, the latter having the outgo either straight as illustrated or with bend to right or left.

Hitherto it has been usual in one form or another to fit a Flushing-rim Hopper or Closet Basin to an ordinary Lead Trap, but the latter being visible from the inside of basin has naturally presented a very unsightly appearance. White enamel paint is sometimes used to cover the lead, but this, it is needless to say, quickly corrodes and becomes even more offensive.

It will be seen from the illustrations that in the "Meteor" Closet with Patent Lead Trap and Seating this has been entirely overcome. The Earthenware Shell is produced at the outgo to fit well into the Lead Trap *beyond the line of sight*, so that the inside of the basin presents exactly the same appearance as a Closet Basin and Trap in one piece of Earthenware.

The Patent Lead Trap and Seating is Steel Moulds or Chills, under great ensuring perfect freedom from air

Front View without Slop Top.

holes. This method of casting is th obtains. Sand castings can never b They are necessarily much heavier th from chills, and, although appare when fixed, may sooner or later, wh develop sand holes and consequent

The Lead Seating is carried water line, so that the Seal of T together independent of the E Basin, which is practically nothin less than a lining to the lead. *should the Basin be broken, the Se is in no way affected.*

The Basin is scored outside Lead Seating is scored inside, an is embedded into the other with of red lead, &c., giving a very thoroughly sound fixture, but, stated, the *Seal of the Trap is independent of this.*

As a Pedestal Closet it is appearance, and may be sup illustrated, also with the out in gold or in perfectly ware. The surface of basin is unusually larg and it will be seen tha beyond the vertical lin if ever soi

A. EMANUEL & SONS, Limited,

SANITARY ENGINEERS,

9, 11 & 13, GEORGE STREET, MANCHESTER SQUARE, LONDON, W.

THE "INFANCLOS," Regd. No. 244780.

ELEVATION.

SECTION.

Water Surface, 8 in. by 6 in.

THE "INFANCLOS" (Regd.)

IN TWO SIZES.

	Height.	Inside diameter at Top.
Infant's	$12\frac{1}{8}$ in.	$9\frac{3}{4}$ in. by $7\frac{3}{4}$ in.
Child's	$12\frac{1}{2}$ in.	11 in. by $7\frac{3}{4}$ in.

A Pedestal Wash-down Closet Apparatus for the use of Infants and Children, as fitted in the London Board Schools and elsewhere.

This Pedestal Closet (Basin and Trap in one piece) is made of extra strong stoneware, white glazed inside. The Trap has a 2 in. inspection arm conveniently placed for unstopping, an arrangement which experience has shewn to be essentially necessary for school use. An earthenware stopper is provided, or the inspection arm may be used for ventilation purposes in the ordinary way. The water surface is exceptionally large, 8 in. by 6 in., and the back of the basin is carried beyond the vertical line. The Cistern, Emanuel's well-known A. B. C. patent, for two or thre gallons flush, is supplied with outgo either tinned lead pipe or screwed for iron barrel, $1\frac{1}{4}$ in. bore be tinned iron) is arranged to pass through a length of Cistern by over-pulling. The whole apparatus is de,

recommended in both cases. The Pull Chain (extra strong galvanized iron barrel, with a stop to prevent any strain on the specially to meet the requirements of the London School Board.

LEAD BURNING TO THE TRAD

For any sized Grati

LEAD CASTING, SHEETS, &c., OF EVERY DESCRIPTION.

JUNCTIONS OR BRANCH PIPES.

LEAD TRAPS—ALL CLASSES.

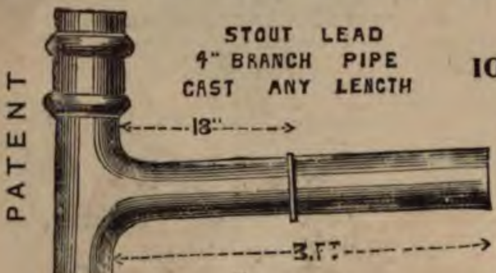


Fig. 1.

Fig. 3.

10 lbs. Cast Lead Foot

—OR—

Pedestal Traps

for Hopper Basins.

The Cheapest and Strongest Trap made, and cannot give way.

Fig. 13.

SINK TRAP, P o

9 lbs. Lead.

The "KENSINGTON"
10 lbs. VALVE CLOSET TRAP.
Self-Cleansing and Unsiphonable.
The Best and Cheapest Valve Closet Trap in the Trade.

Fig. 2.

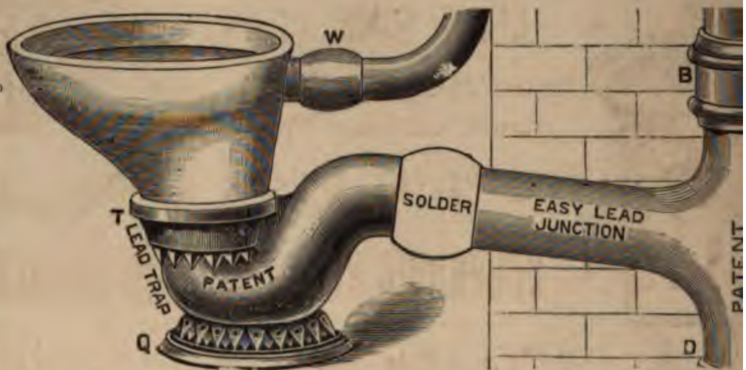


Fig. 3.

LEAD SOIL PIPE SOCKETS

WITH OR WITHOUT EARS

Fig. 4.
LEAD SOIL PATENT SOCKETS & JOINTS.

Fig. 6.

Fig. 5.

AND SOIL PIPE JOINT SCREENS.

WEST LONDON LEAD WORK

Proprietor—P. J. DAVIES.

Office: 78, EARL'S COURT ROAD, LONDON

WRITE FOR PRICE LIST.

LEAD TACKS.

Fig. 8.

Fig. 7

REGISTERED PATTERN TACKS.

Made in sizes varying from ½-in. to 6-in. lead pipe. In ordering, state size of pipe only. These celebrated and much-favoured Tacks or Ears surpass all other Tacks or Pipe Clips in the market.

Price, 1½d. per lb. above price of old lead.

We have over 100 sets of other moulds to choose from.

Fig. 9.

LEAD SINK CONES.

Lead Heads and Finials made to any Pattern.

Fig. 10.

ROYAL PALACE Patent SINK CONE and STRAIGHT PIPE TRAP.

Unsiphonable. Complete with 4-in. Grating.

LEAD PATENT BURNING MACHINES, BLOWERS, AND FITTINGS.

SULPHURIC ACID FOR LEAD BURNERS.

SPELTER for LEAD BURNERS.

Iron Solder Moulds, Stick Lead Moulds.

Well Sinker and Well Borer to any depth.

PUMPS OF EVERY DESCRIPTION.

Fig. 12.

Write for List of Prices, &c., to—

P. J. DAVIES,

Lead Trap Manufacturer, Plumber, Lead Burner,
Sheet and General Lead Caster to the Trade,

78, EARL'S COURT ROAD, KENSINGTON, LONDON.